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Shibayama et al.

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(54) **SPECTROSCOPIC SENSOR INCLUDING INTERFERENCE FILTER UNIT HAVING SILICON OXIDE CAVITY**

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G01J 3/26 (2006.01)
G01J 3/02 (2006.01)
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(52) **U.S. Cl.**
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CPC G01J 3/45; G01J 3/513; G01J 3/2803; G01J 3/36; G01J 3/0259; G01J 3/26;
(Continued)

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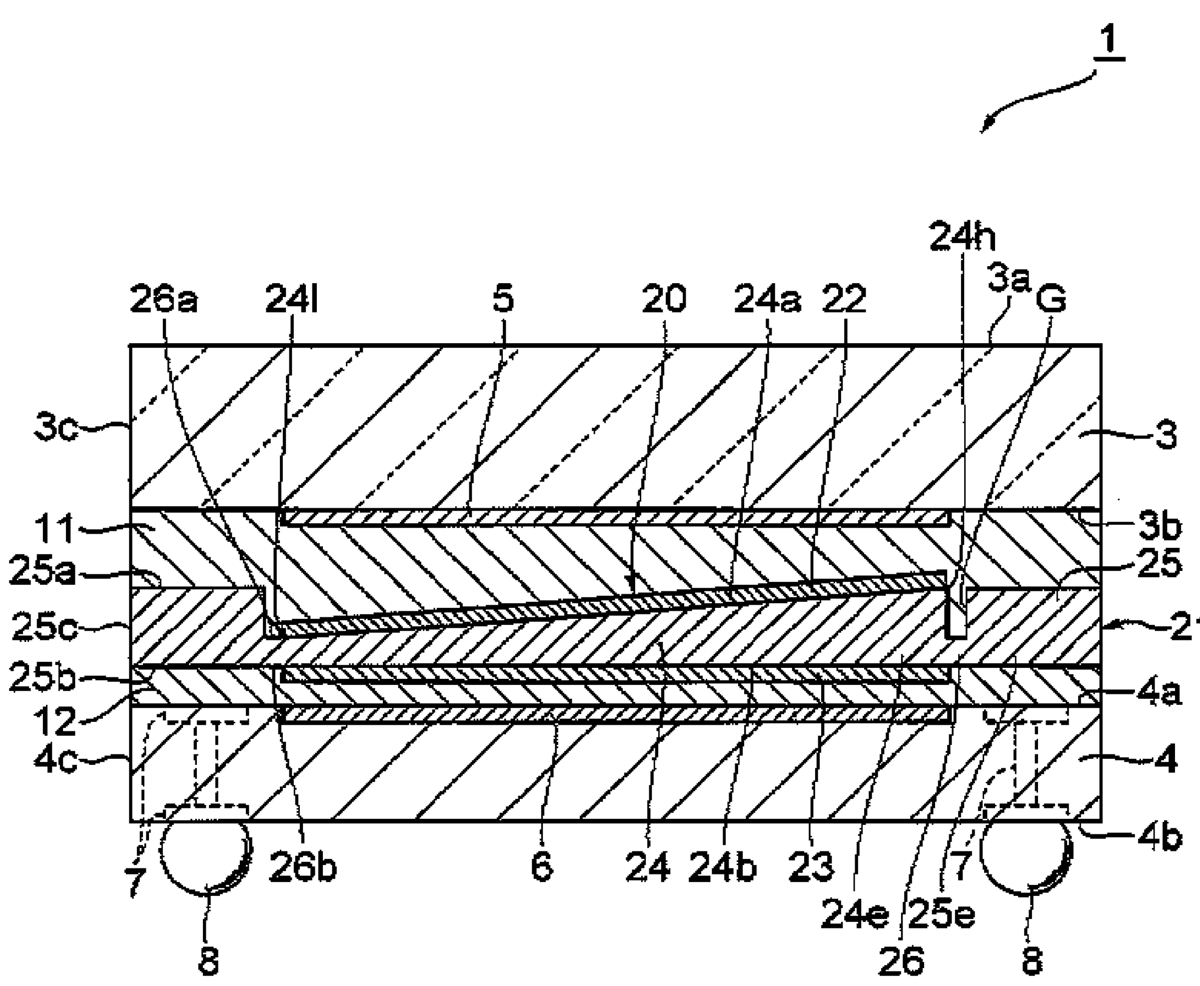
(74) *Attorney, Agent, or Firm* — Drinker Biddle & Reath LLP

(57) **ABSTRACT**

A spectroscopic sensor **1** comprises an interference filter unit **20**, having a cavity layer **21** and first and second mirror layers **22**, **23** opposing each other through the cavity layer **21**, for selectively transmitting therethrough light in a predetermined wavelength range according to an incident position thereof; a light-transmitting substrate **3**, arranged on the first mirror layer **22** side, for transmitting therethrough light incident on the interference filter unit **20**, a light-detecting substrate **4**, arranged on the second mirror layer **23** side, for detecting the light transmitted through the interference filter unit **20**, and a first coupling layer **11** arranged between the interference filter unit **20** and the light-transmitting substrate **3**. The cavity layer **21** and the first coupling layer **11** are silicon oxide films.

7 Claims, 22 Drawing Sheets



(51) **Int. Cl.**
G01J 3/36 (2006.01)
G01J 3/51 (2006.01)
G01J 3/12 (2006.01)
G01J 3/28 (2006.01)

(52) **U.S. Cl.**
CPC ***G01J 3/36*** (2013.01); ***G01J 3/513*** (2013.01); *G01J 2003/1234* (2013.01); *G01J 2003/2806* (2013.01); *G01J 2003/2816* (2013.01)

(58) **Field of Classification Search**
CPC G01J 2003/2806; G01J 2003/1234; G01J 2003/2816
See application file for complete search history.

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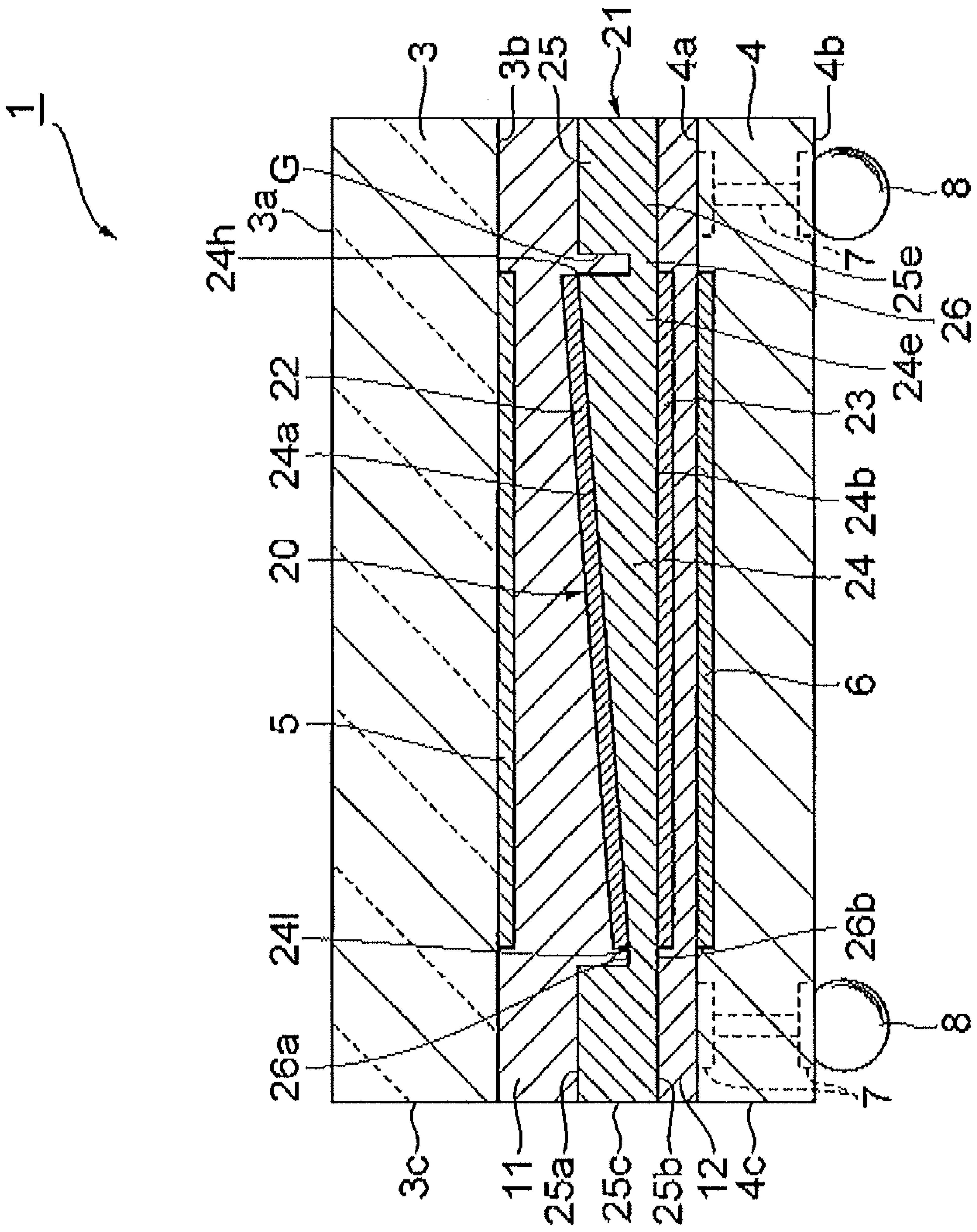
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25b
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4c

Fig.1

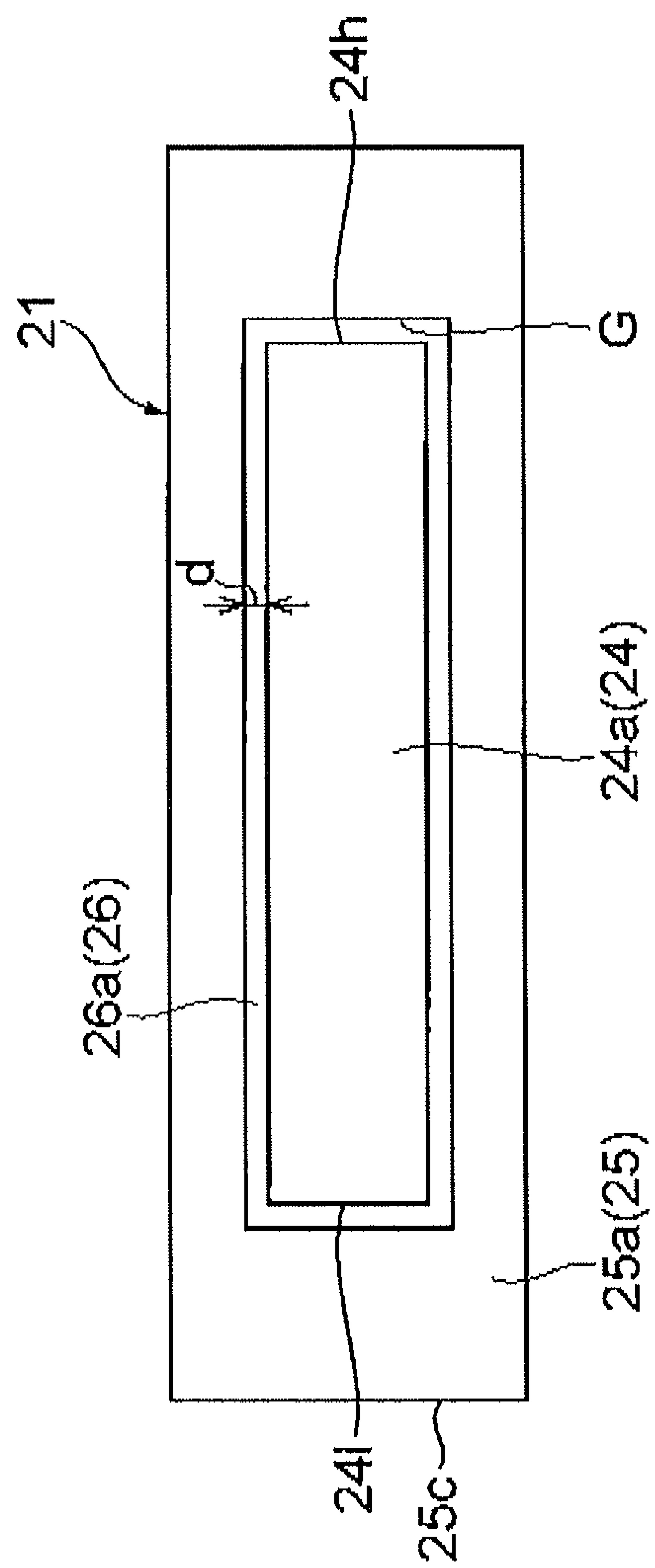


Fig.2

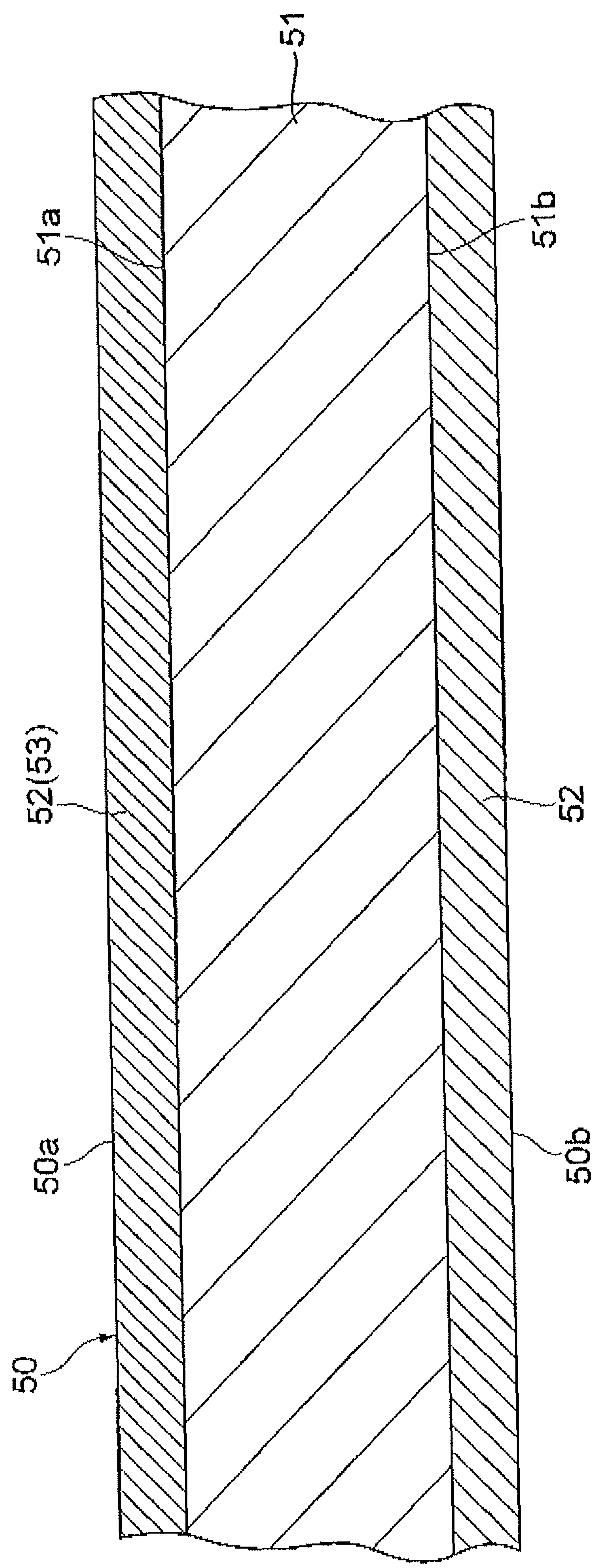
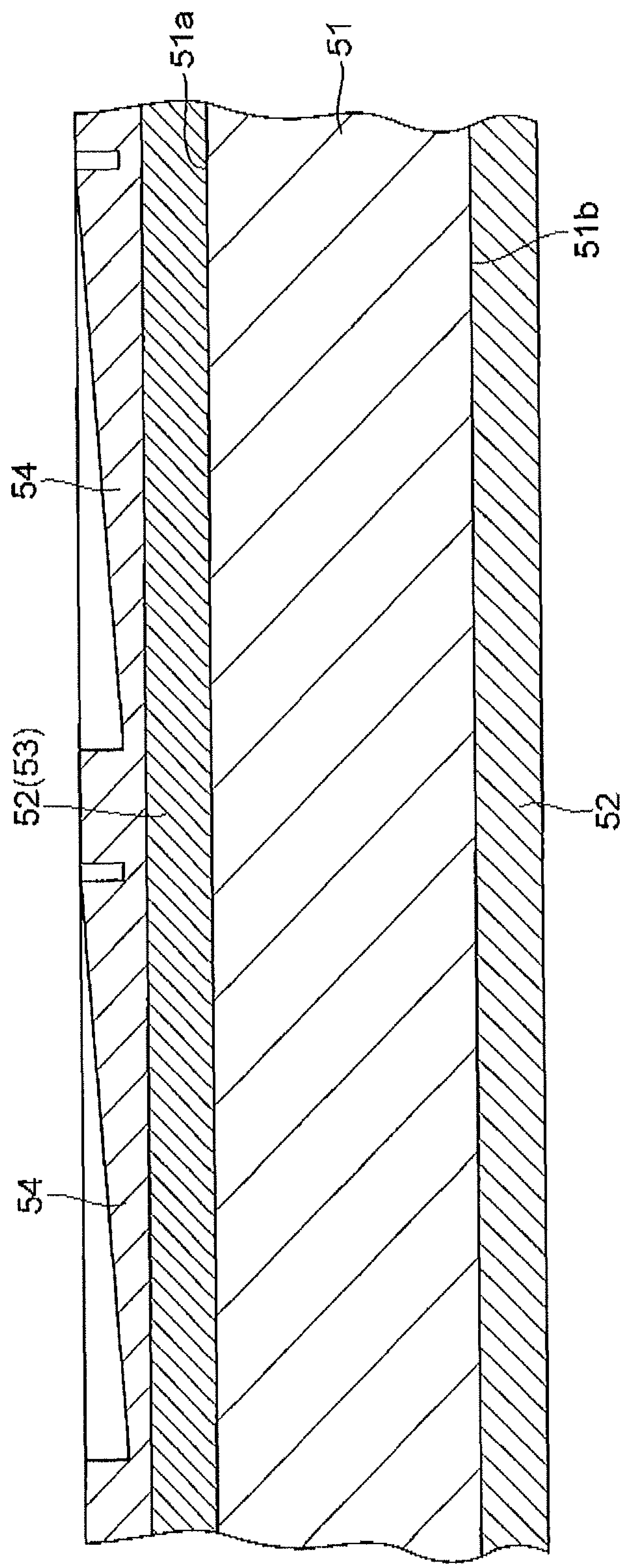


Fig.3



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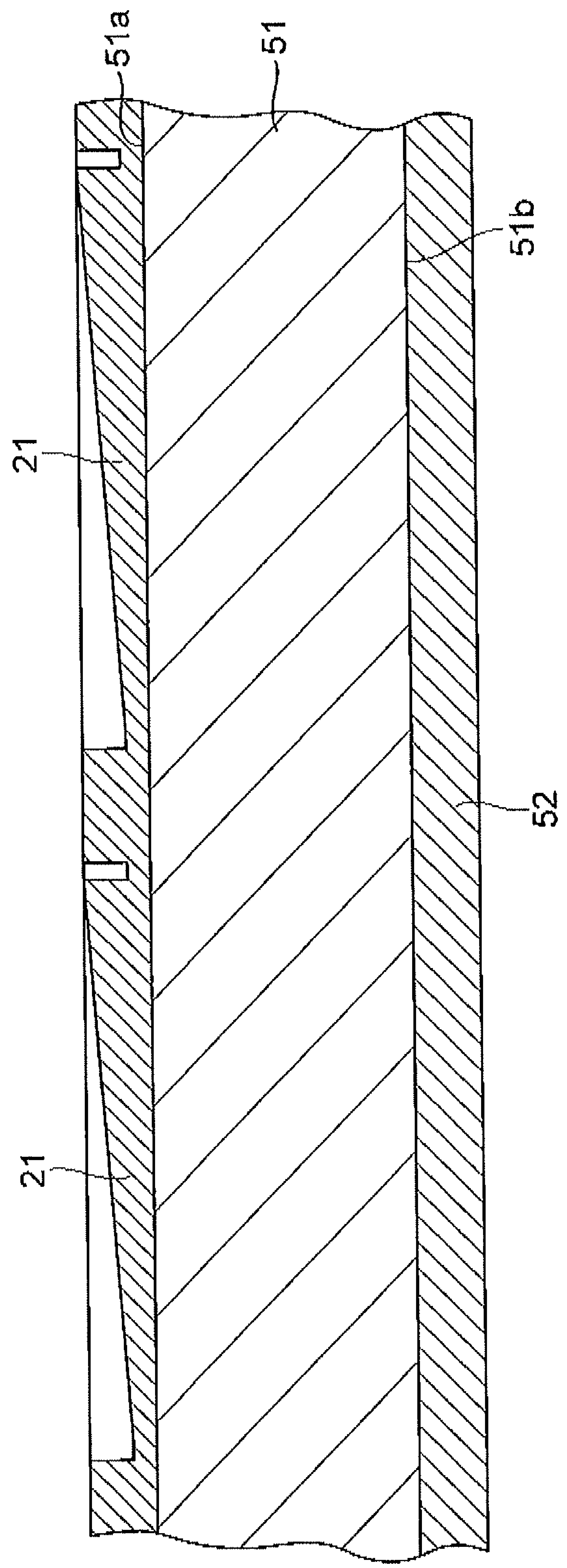


Fig.5

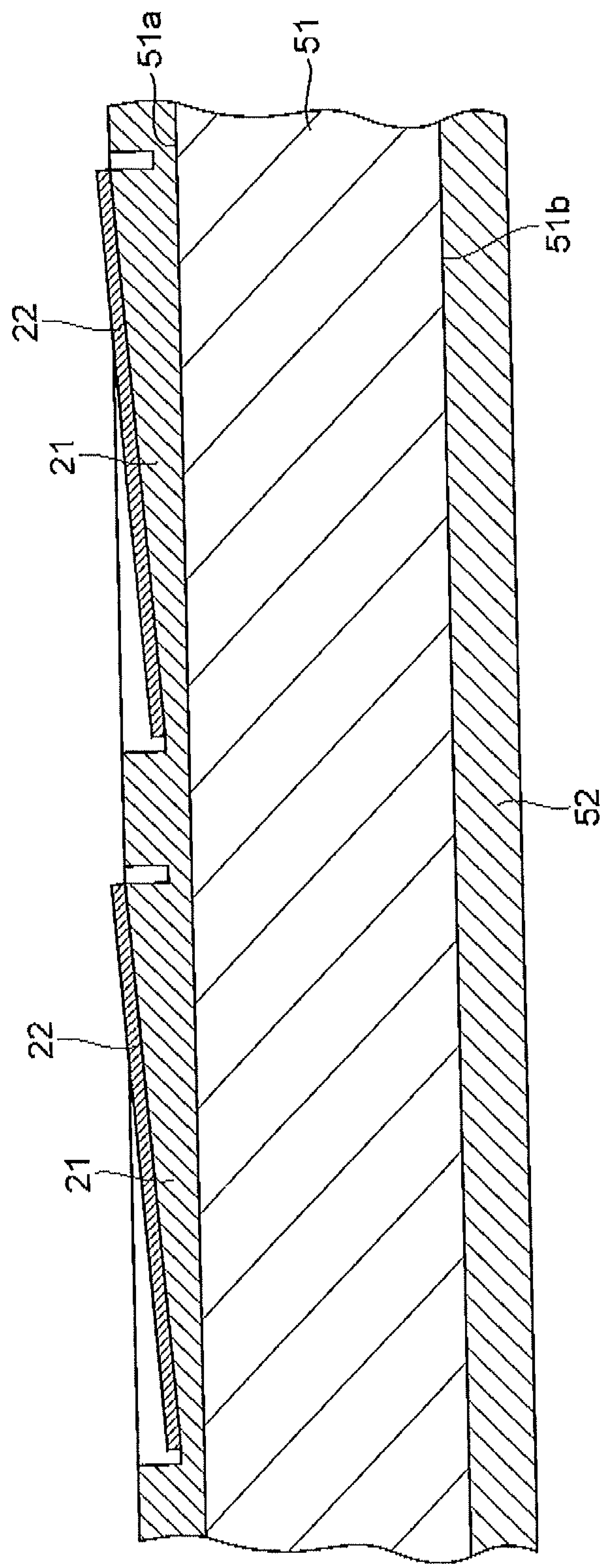
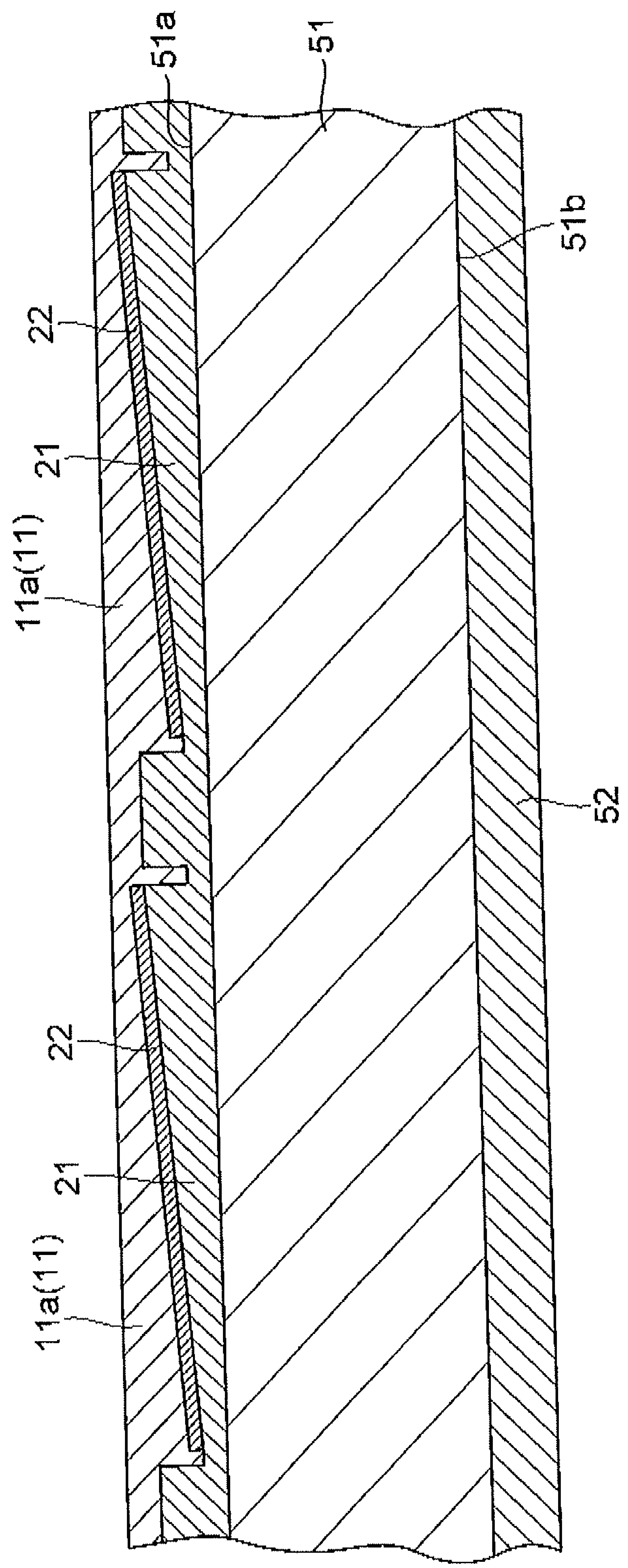


Fig.6



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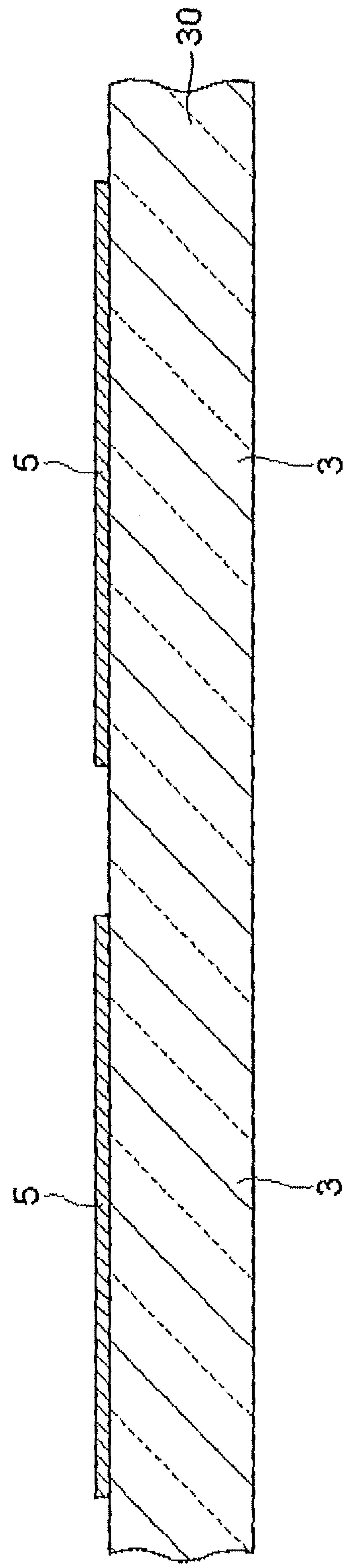


Fig.8

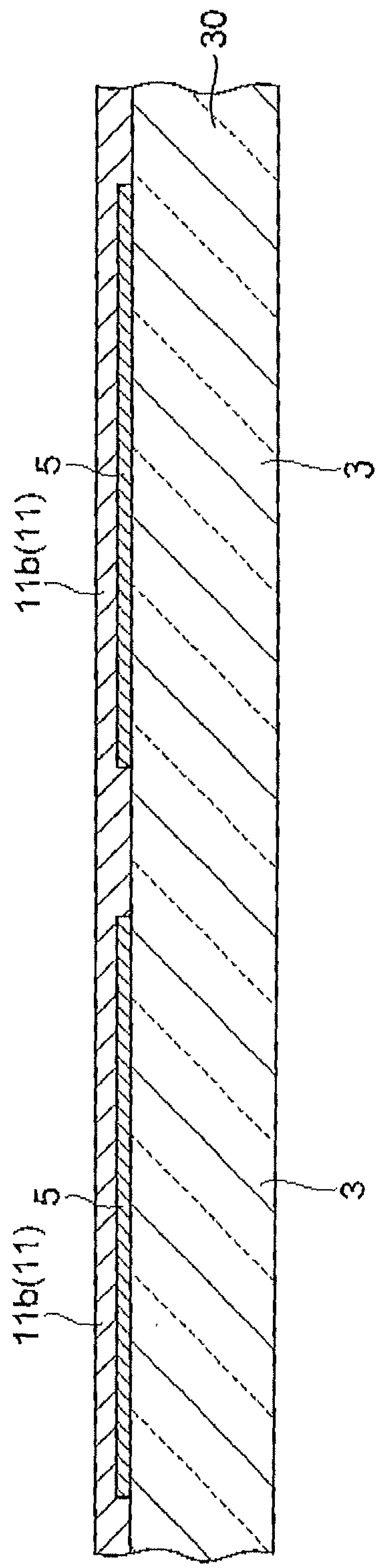
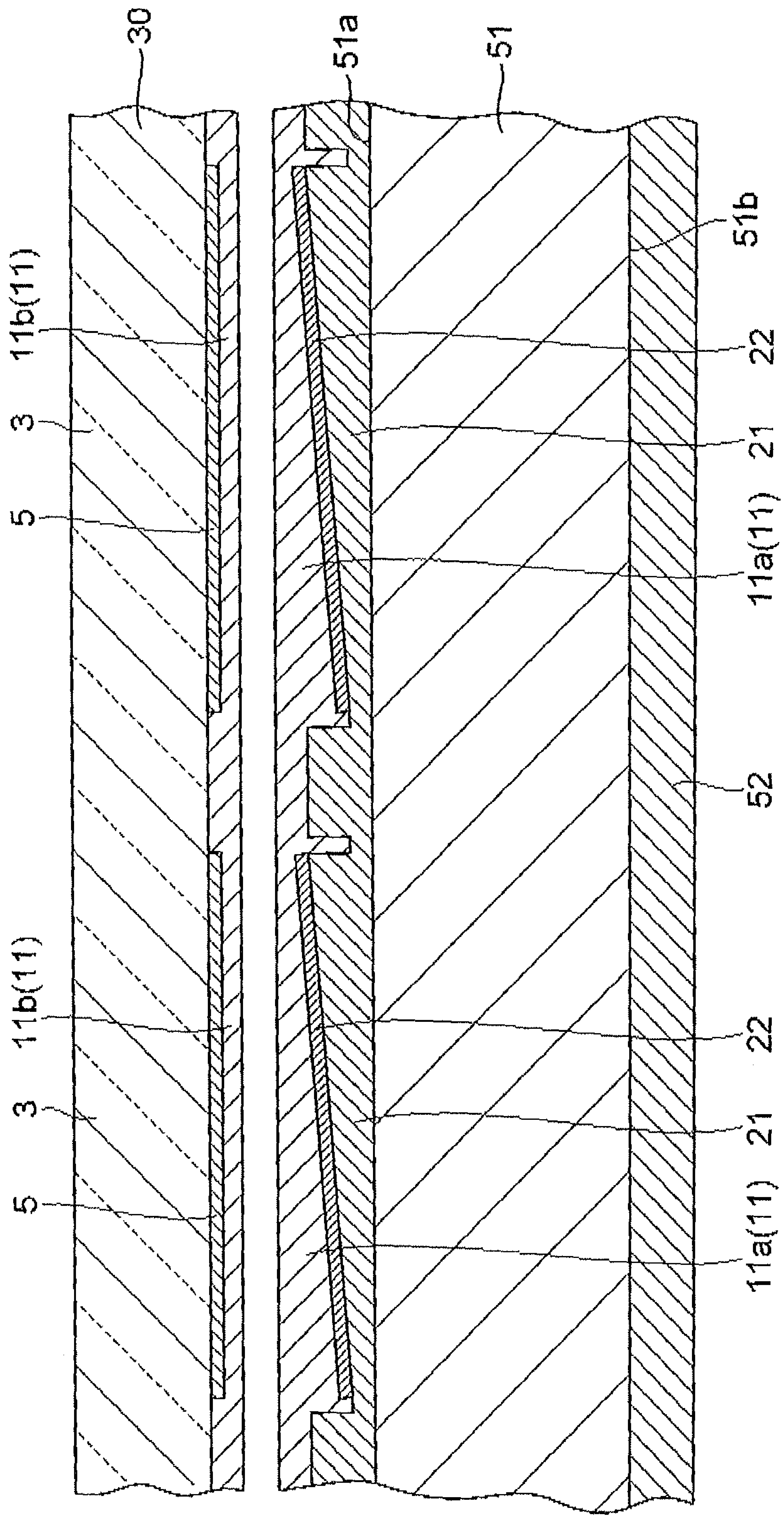


Fig.9

Fig.10



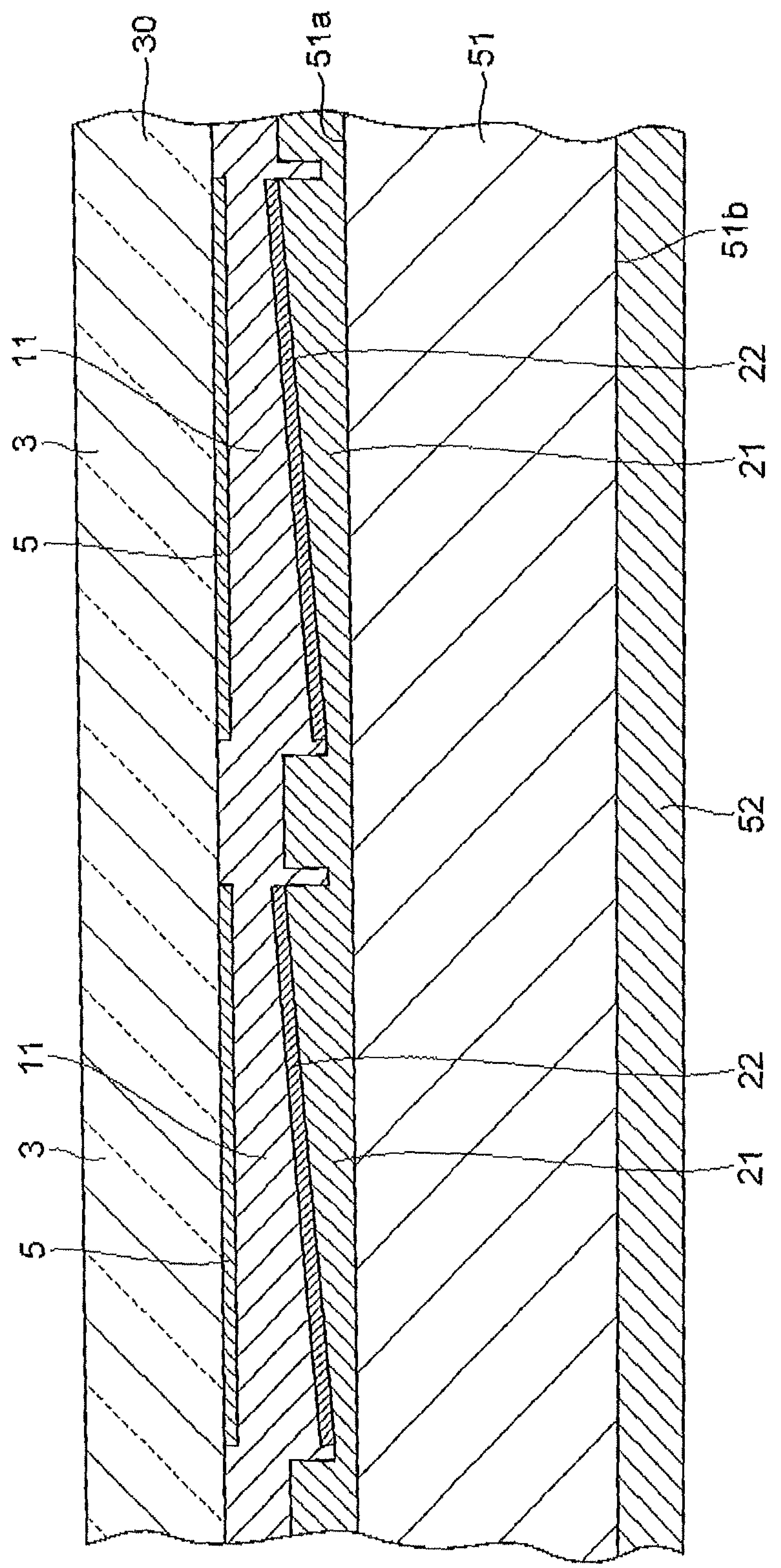
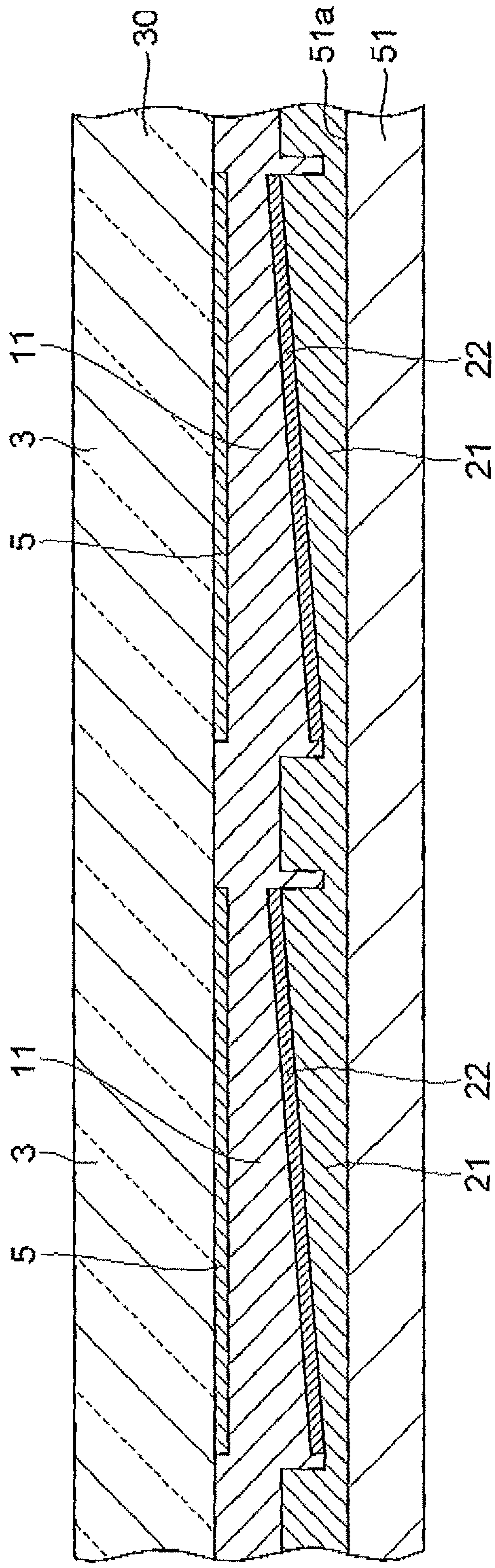


Fig.11



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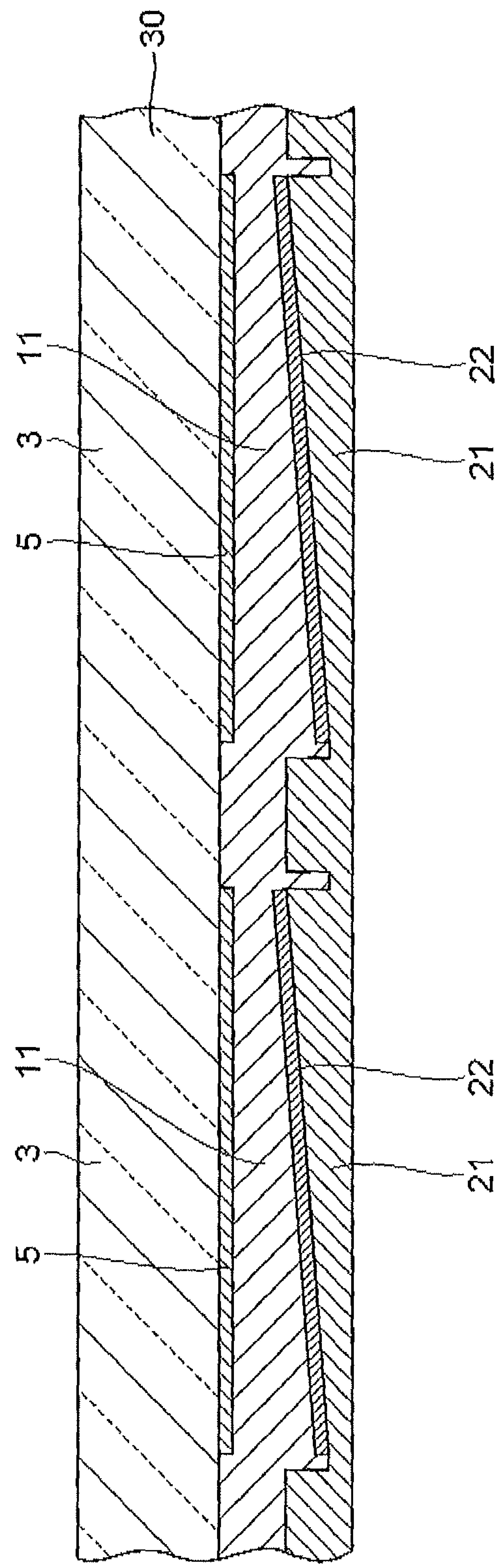


Fig. 13

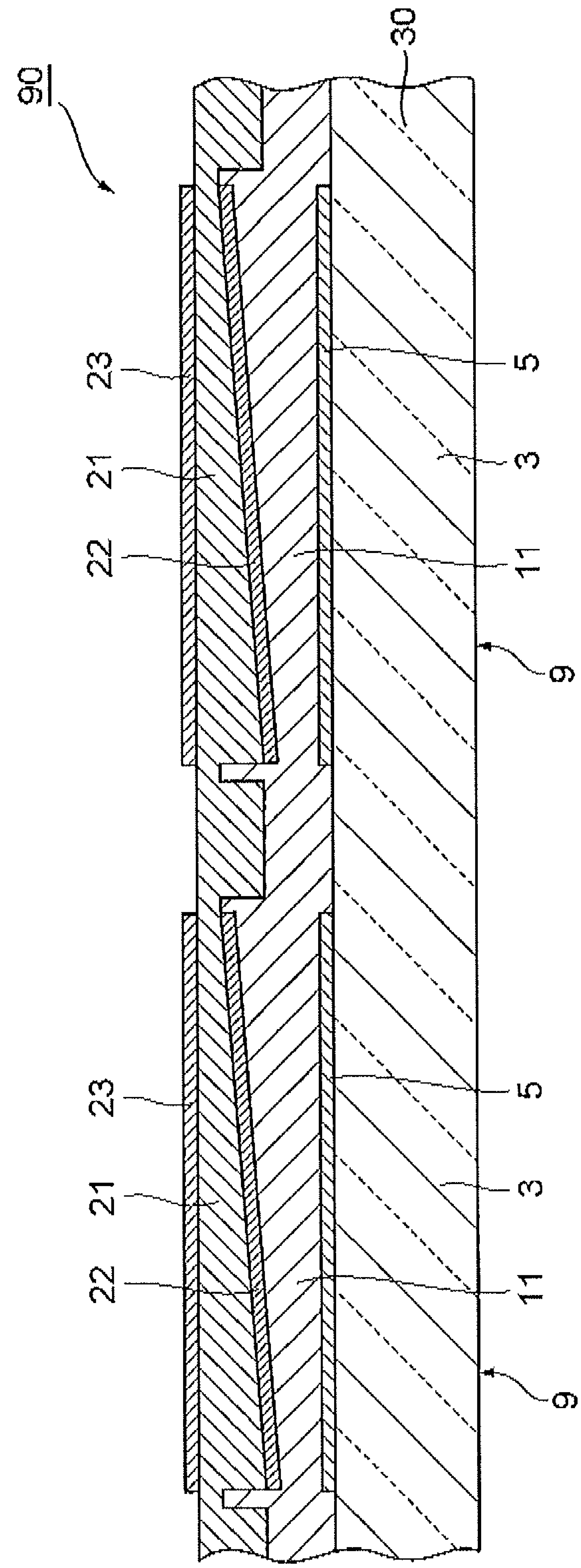


Fig.14

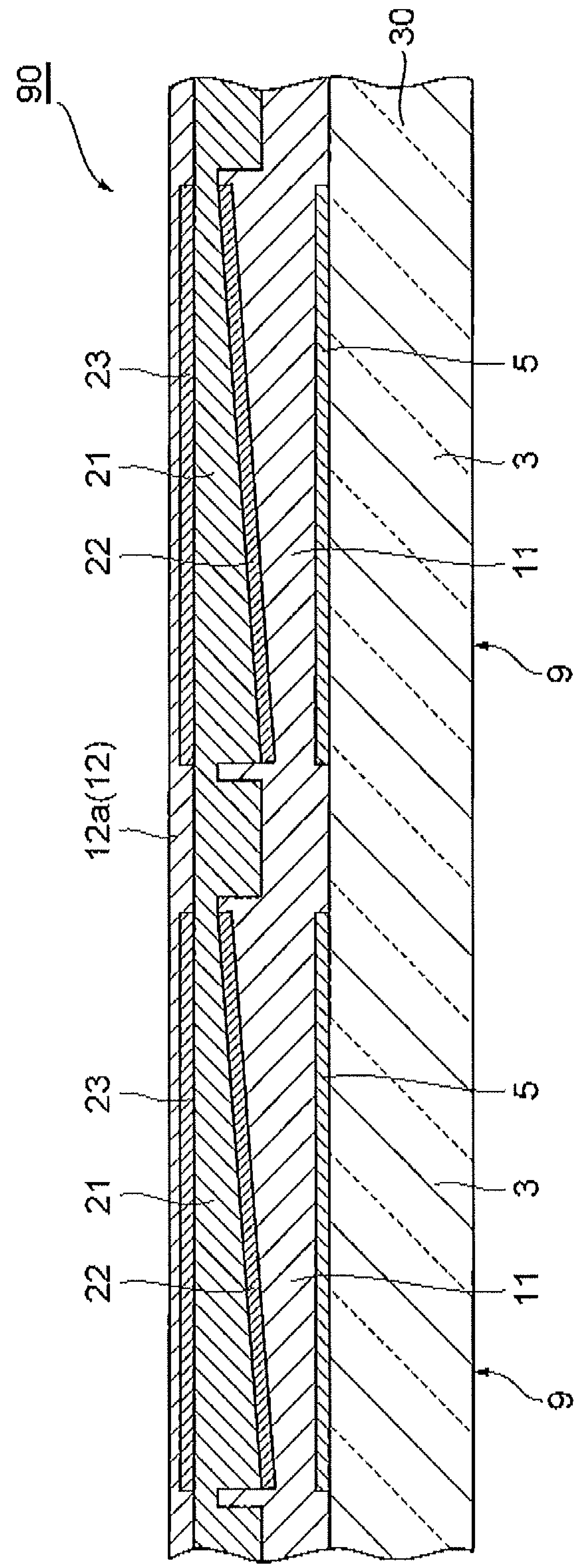


Fig.15

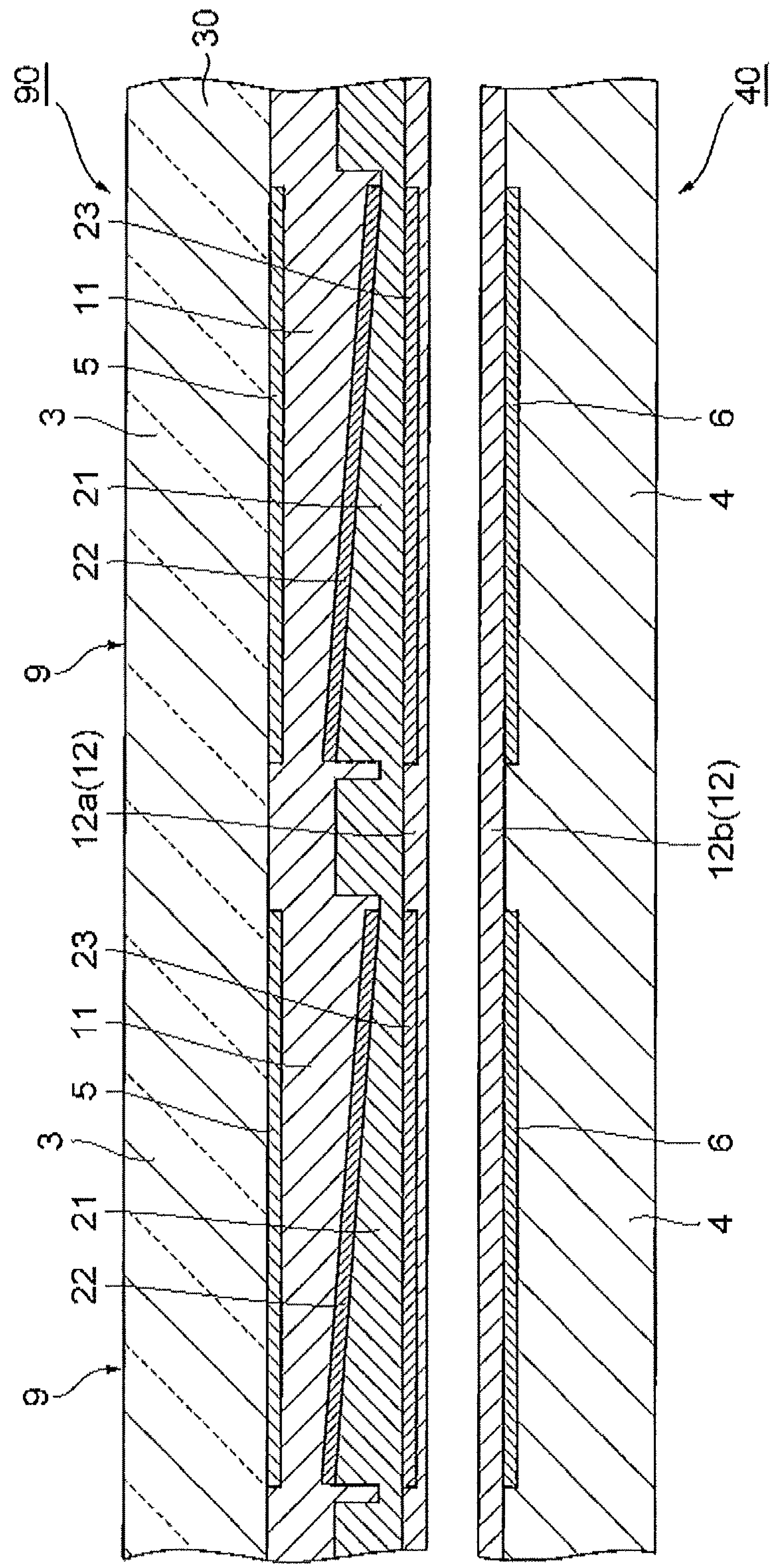


Fig.16

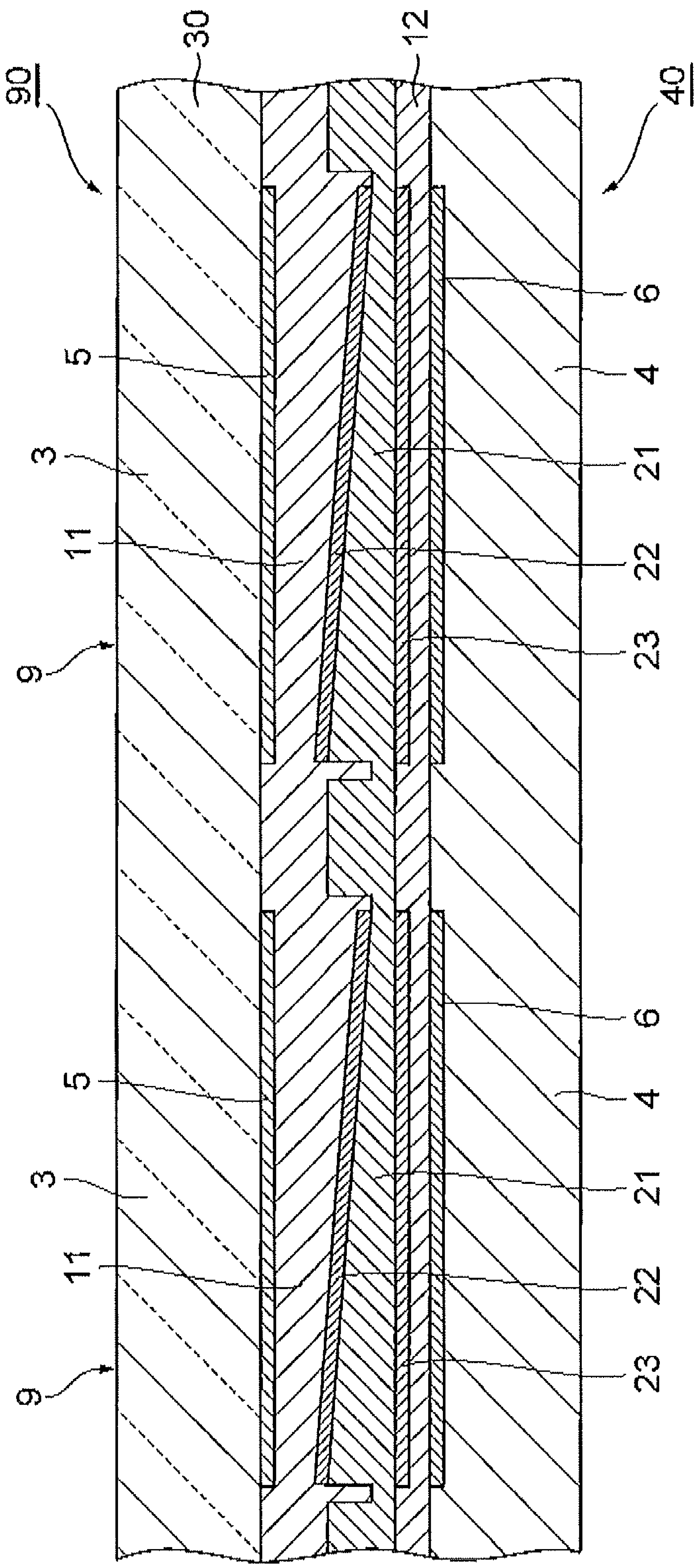


Fig.17

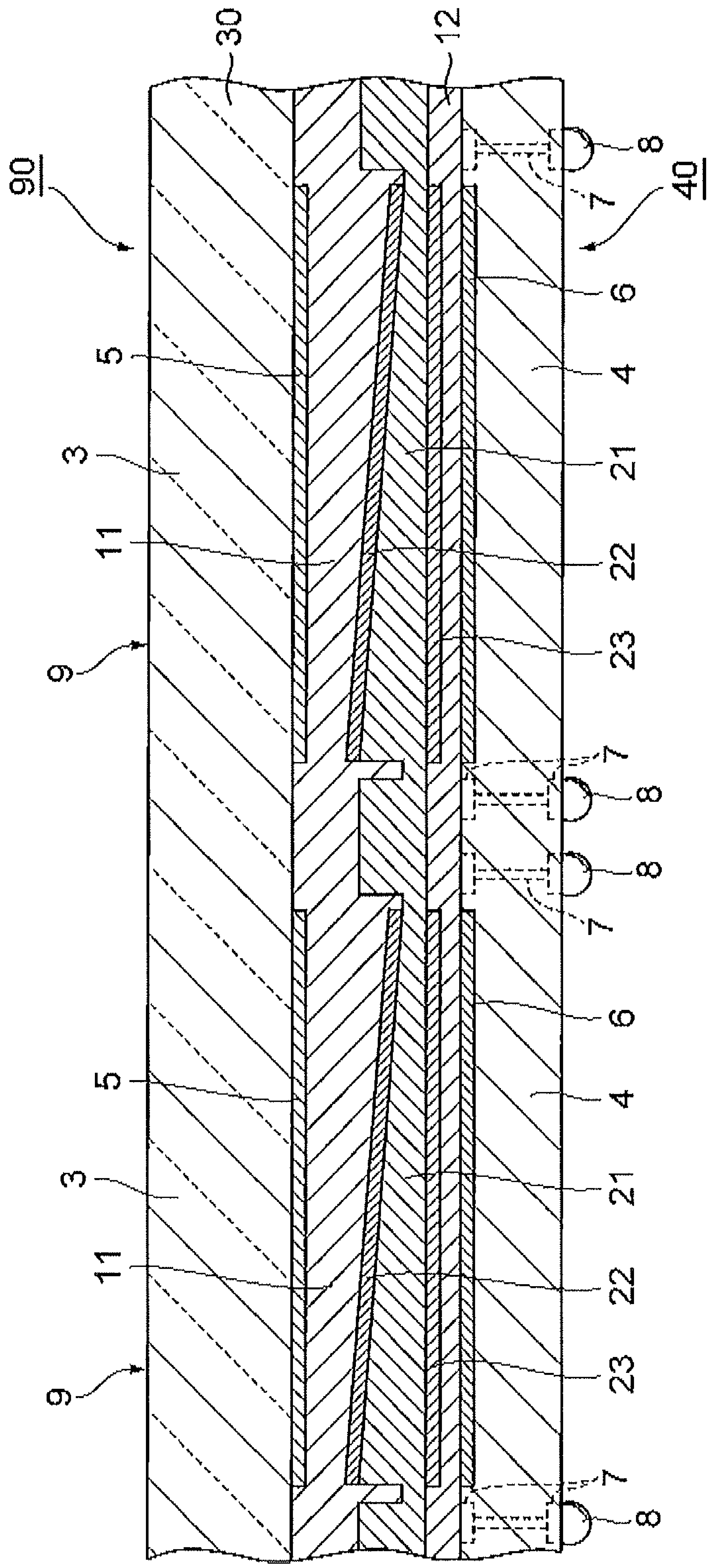


Fig.18

Fig.19

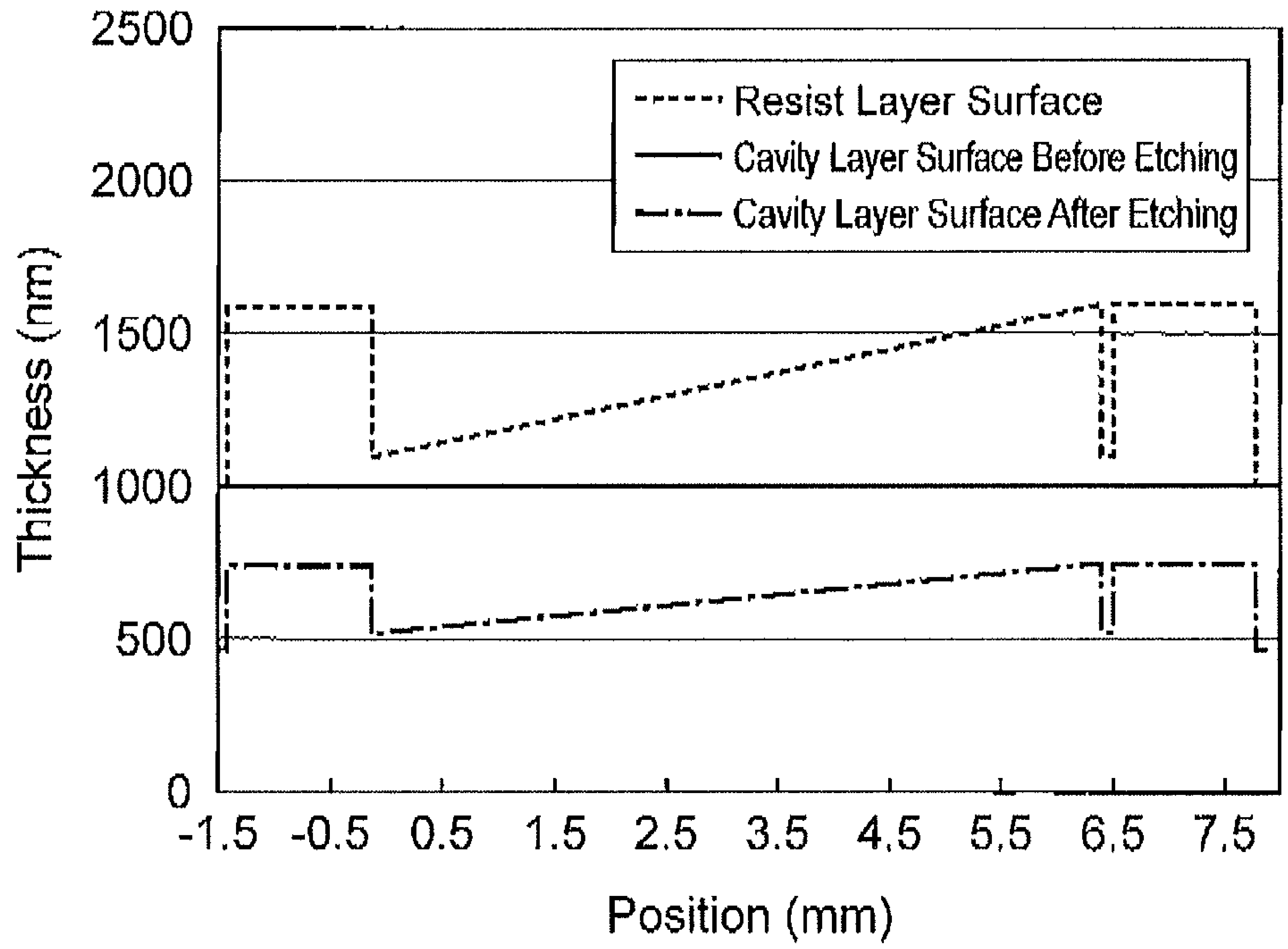
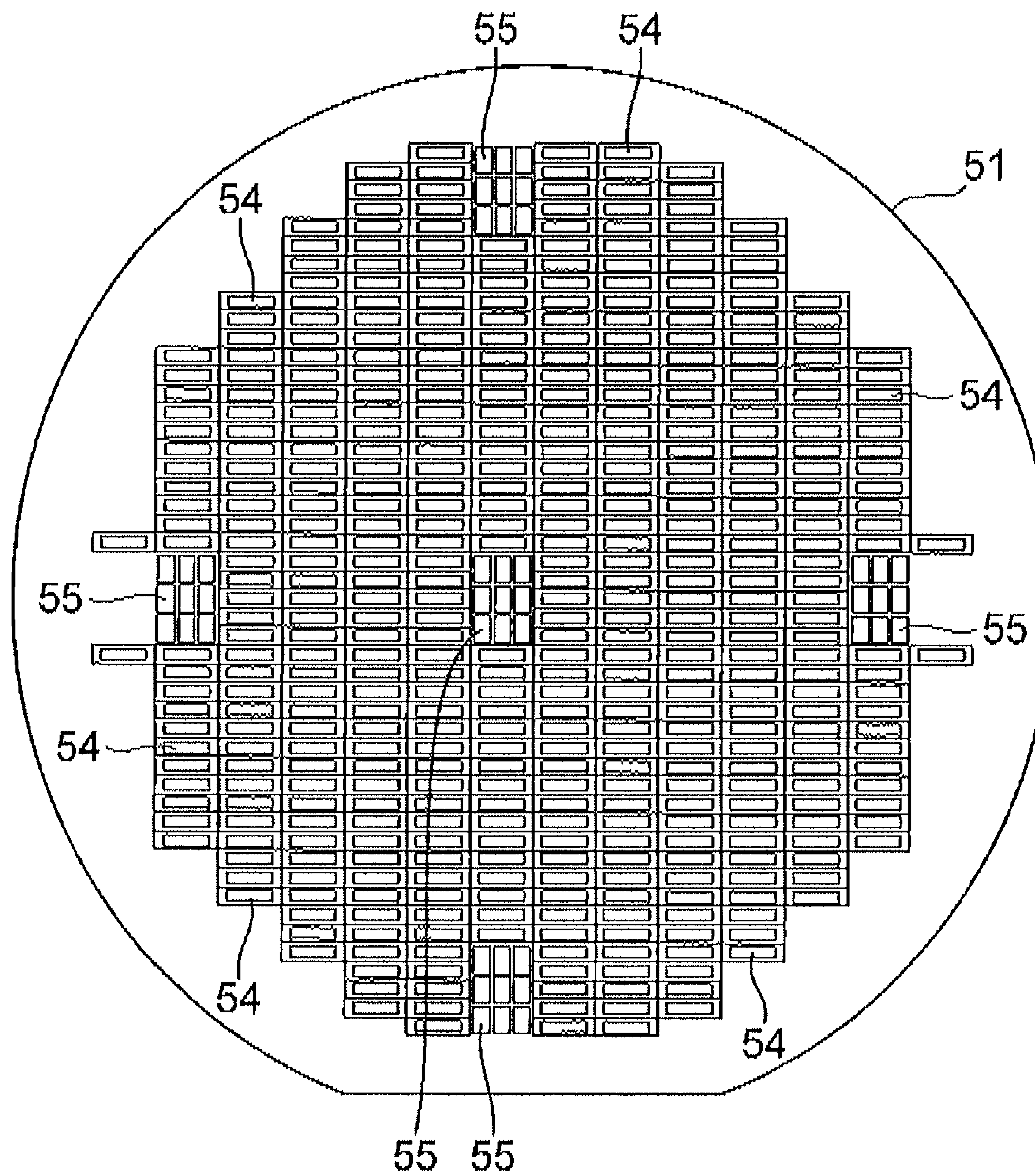

Resist Layer Surface
Cavity Layer Surface Before Etching
Cavity Layer Surface After Etching
Thickness (nm)
2500
2000
1500
1000
500
0
-1.5 -0.5 0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5
Position (mm)

Fig.20



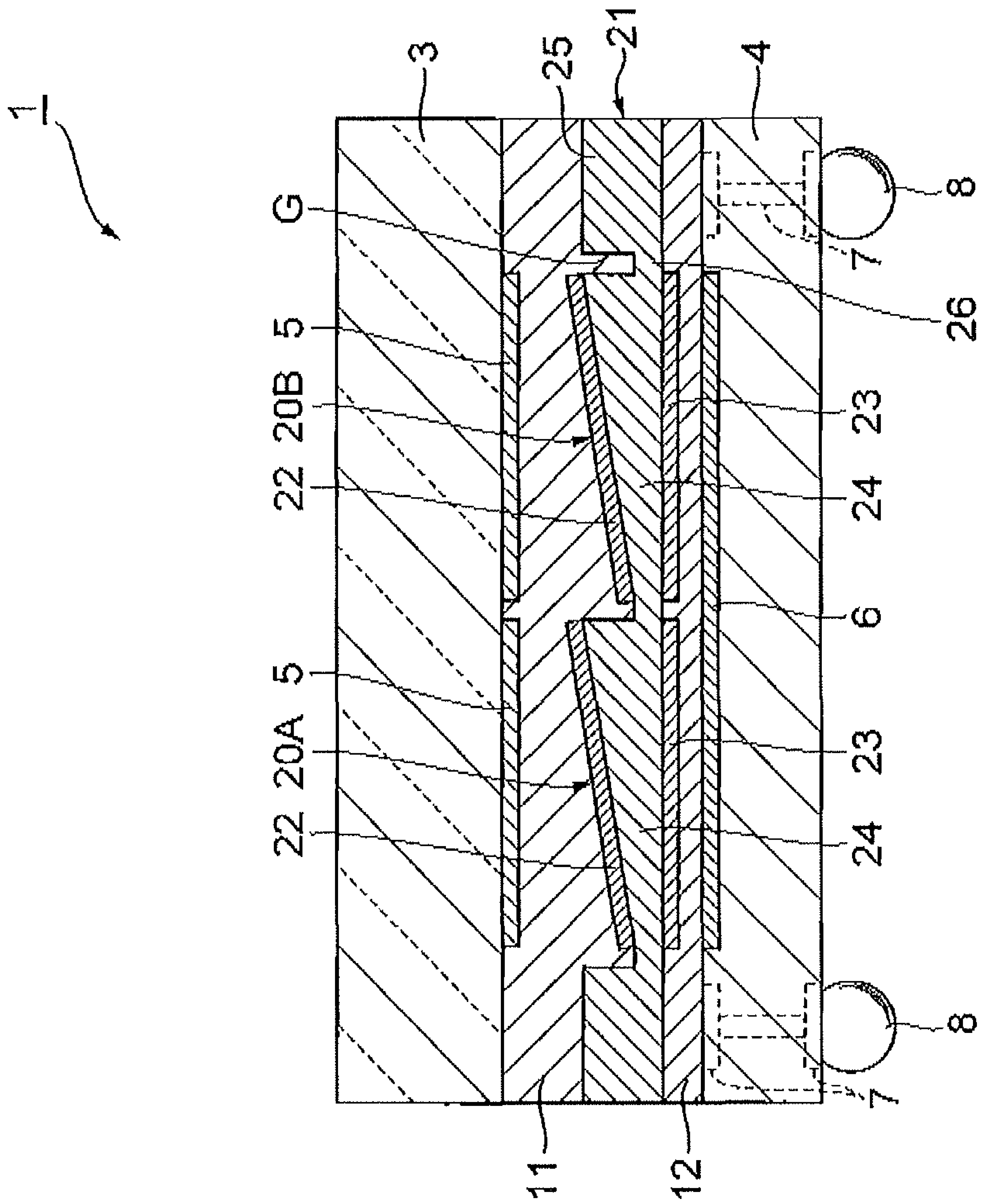


Fig.21

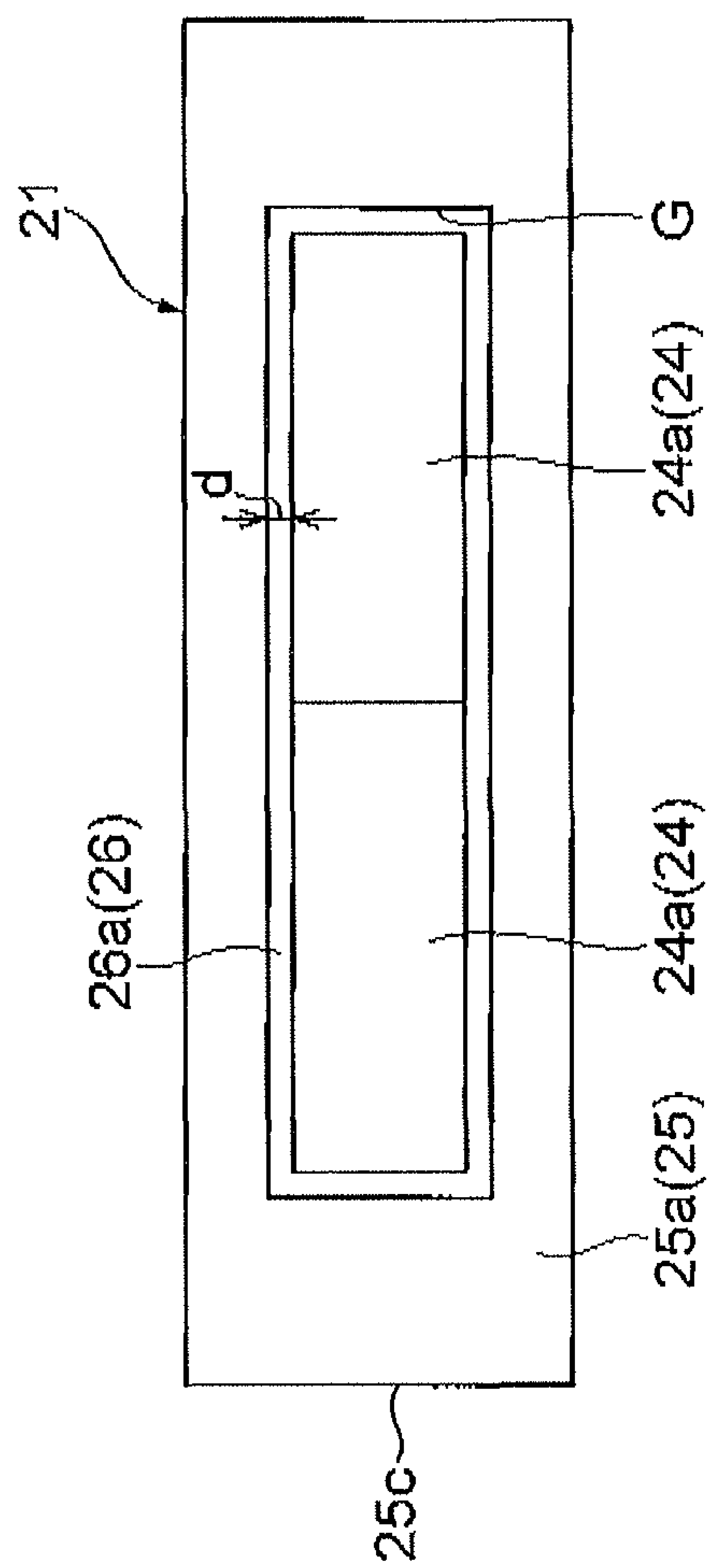


Fig.22

SPECTROSCOPIC SENSOR INCLUDING INTERFERENCE FILTER UNIT HAVING SILICON OXIDE CAVITY

TECHNICAL FIELD

The present invention relates to a spectroscopic sensor.

BACKGROUND ART

Known as a conventional spectroscopic sensor is one comprising an interference filter unit for transmitting therethrough light having a predetermined wavelength according to an incident position of light, a light-transmitting substrate for transmitting therethrough the light incident on the interference filter unit, and a light-detecting substrate for detecting the light transmitted through the interference filter unit. Here, a pair of mirror layers may oppose each other through a cavity layer so as to construct the interference filter unit as that of Fabry-Perot type (see, for example, Patent Literatures 1 and 2).

CITATION LIST

Patent Literature

Patent Literature 1: Japanese Patent Application Laid-Open No. 2006-58301
Patent Literature 2: Japanese Translated International Application Laid-Open No. H02-502490

SUMMARY OF INVENTION

Technical Problem

When a resin material is used as a material for the cavity layer, a coupling layer arranged between the interference filter unit and the light-transmitting substrate, and the like in the spectroscopic sensor such as the one mentioned above, however, the cavity layer, the coupling layer, and the like may be degraded by changes in temperature, high humidity, and the like of the environment where they are in use,

It is therefore an object of the present invention to provide a highly reliable spectroscopic sensor.

Solution to Problem

A spectroscopic sensor in accordance with one aspect of the present invention comprises an interference filter unit, having a cavity layer and first and second mirror layers opposing each other through the cavity layer, for selectively transmitting therethrough light in a predetermined wavelength range according to an incident position thereof; a light-transmitting substrate, arranged on the first mirror layer side, for transmitting therethrough light incident on the interference filter unit; a light-detecting substrate, arranged on the second mirror layer side, for detecting the light transmitted through the interference filter unit; and a first coupling layer arranged between the interference filter unit and the light-transmitting substrate; while the cavity layer and the first coupling layer are silicon oxide films.

In this spectroscopic sensor, the cavity layer is a silicon oxide film and thus can stabilize its form, light transmittance, refractive index, and the like more than when made of a resin material. The first coupling layer is also a silicon oxide film and thus can stabilize the transmission characteristic of the light advancing from the light-transmitting

substrate to the interference filter unit. The fact that the cavity layer and first coupling layer are silicon oxide films can also prevent their quality from being degraded by changes in temperature, high humidity, and the like of the environment where they are in use. Hence, this spectroscopic sensor is highly reliable.

Here, the cavity layer may be a silicon oxide film formed by thermally oxidizing silicon. This stably yields the cavity layer with high quality at low cost.

The first coupling layer may be a silicon oxide film formed by a film forming process using TEOS as a material gas. This can form the first coupling layer at low temperature and high speed with low stress, so as to prevent the cavity layer and first and second mirror layers from being damaged, whereby the cavity layer and first and second mirror layers are obtained with high quality.

The spectroscopic sensor may further comprise a second coupling layer arranged between the interference filter unit and the light-detecting substrate, while the second coupling layer may be a silicon oxide film. This can stabilize the transmission characteristic of the light advancing from the interference filter unit to the light-detecting substrate more than when the second coupling layer is made of a resin material. The fact that the second coupling layer is a silicon oxide film in addition to both of the cavity layer and first coupling layer can more reliably prevent their quality from being degraded by changes in temperature, high humidity, and the like of the environment where they are in use.

The second coupling layer may be a silicon oxide film formed by a film forming process using TEOS as a material gas. This can form the second coupling layer at low temperature and high speed with low stress, so as to prevent the cavity layer and first and second mirror layers from being damaged, whereby the cavity layer and first and second mirror layers are obtained with high quality.

The spectroscopic sensor may further comprise an optical filter layer, formed on the light-transmitting substrate so as to oppose the first mirror layer, for transmitting therethrough light in the predetermined wavelength range. This can make the light in the predetermined wavelength range efficiently incident on the interference filter unit.

Advantageous Effects of Invention

The present invention can provide a highly reliable spectroscopic sensor.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a vertical sectional view of a spectroscopic sensor in accordance with an embodiment of the present invention;

FIG. **2** is a plan view of a cavity layer in the spectroscopic sensor of FIG. **1**;

FIG. **3** is a vertical sectional view for explaining a method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **4** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **5** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **6** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **7** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **8** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **9** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **10** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **11** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **12** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **13** is a vertical, sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **14** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **15** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **16** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **17** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **18** is a vertical sectional view for explaining the method for manufacturing the spectroscopic sensor of FIG. **1**;

FIG. **19** is a profile chart illustrating the relationship between a resist layer and the cavity layer;

FIG. **20** is a plan view of a handle substrate formed with the resist layer;

FIG. **21** is a vertical sectional view of a modified example of the spectroscopic sensor of FIG. **1**; and

FIG. **22** is a plan view of the cavity layer in the spectroscopic sensor of FIG. **20**.

DESCRIPTION OF EMBODIMENTS

In the following, preferred embodiments of the present invention will be explained in detail with reference to the drawings. In the drawings, the same or equivalent parts will be referred to with the same signs while omitting their overlapping descriptions.

As FIG. **1** illustrates, a spectroscopic sensor **1** comprises an interference filter unit **20** for selectively transmitting therethrough light in a predetermined wavelength range according to an incident position thereof, a light-transmitting substrate **3** for transmitting therethrough the light incident on the interference filter unit **20**, and a light-detecting substrate **4** for detecting the light transmitted through the interference filter unit **4**. The spectroscopic sensor **1** is constructed as a rectangular parallelepiped CSP (Chip Size Package) in which each side has a length of several hundred μm to several ten mm.

The light-transmitting substrate **3** is made of glass or the like and formed into a rectangular plate having a thickness on the order of 0.2 to 2 mm. An optical filter layer **5** is formed on the rear face **3***b* of the light-transmitting substrate **3** so as to oppose the interference filter unit **20**. The optical filter layer **5**, which is a dielectric multilayer film or organic color filter (color resist), is formed into a rectangular film having a thickness on the order of 0.1 to 10 μm. The optical filter layer **5** functions as a bandpass filter for transmitting therethrough light in the predetermined wavelength range to be incident on its opposed interference filter unit **20**.

The light-detecting substrate **4**, which is a photodiode array, is formed into a rectangular plate having a thickness on the order of 10 to 150 μm. The front face **4***a* of the light-detecting substrate **4** is formed with a light-receiving unit **6** for receiving the light transmitted through the interference filter unit **20**. The light-receiving unit **6** is constructed by one-dimensionally arranging elongated photodiodes along the longitudinal direction of the light-detecting substrate **4**, while each photodiode extends along a direction substantially perpendicular to the longitudinal direction of the light-detecting substrate **4**. The light-detecting substrate **4** is further formed with leads **7** (front wiring, back wiring, through wiring, etc.) for taking out electric signals photoelectrically converted by the light-receiving unit **6**. The rear face **4***b* of the light-detecting substrate **4** is provided with surface-mounting bumps **8** electrically connected to the leads **7**. The light-detecting substrate **4** is not limited to a photodiode array, but may also be any of other semiconductor light-detecting elements (C-MOS image sensors, CCD image sensors, and the like).

The interference filter unit **20** has a cavity layer **21** and DBR (Distributed Bragg Reflector) layers **22**, **23**. In the interference filter unit **20**, the DBR layers (first and second mirror layers) **22**, **23** oppose each other through the cavity layer **21**. That is, the cavity layer **21** keeps a distance between the DBR layers **22**, **23** opposing each other. Each of the DBR layers **22**, **23** is a dielectric multilayer film made of SiO_2, TiO_2, Ta_2O_5, Nb_2O_5, Al_2O_3, MgF_2, or the like and formed into a rectangular film having a thickness on the order of 0.1 to 10 μm.

The cavity layer **21** is a silicon oxide film (SiO_2 film), formed by thermally oxidizing silicon, having a thickness on the order of 100 nm to several μm. As FIGS. **1** and **2** illustrate, the cavity layer **21** has a filter region **24**, a surrounding region **25**, and a connecting region **26** which are formed integrally.

The filter region **24** is formed into a rectangular film, in which each side has a length on the order of several mm, and held between the DBR layers **22**, **23**. More specifically, the DBR layer **22** is formed on the front face **24***a* of the filter region **24**, while the DBR layer **23** is formed on the rear face **24***b* of the filter region **24**. The rear face **24***b* of the filter region **24** is substantially parallel to a plane perpendicular to the incident direction of light (the direction in which the light-transmitting substrate **3** and the light-detecting substrate **4** oppose each other), while the front face **24***a* of the filter region **24** is tilted with respect to this plane. As a consequence, the filter region **24** gradually increases its thickness on the order of 100 nm to several μm toward one longitudinal end of the spectroscopic sensor **1**.

The surrounding region **25** is formed into a rectangular annular shape, in which each outer side has a length on the order of several mm, and surrounds the filter region **24** with a predetermined distance d (e.g., on the order of several μm to 1 mm) therefrom. The connecting region **26** is formed into a rectangular annular shape so as to be placed between the filter region **24** and surrounding region **25** and connects an end part **24***e* of the filter region **24** on the light-detecting substrate **4** side and an end part **25***e* of the surrounding region **25** on the light-detecting substrate **4** side to each other. The filter region **24**, surrounding region **25**, and connecting region **26** form a groove G which extends such as to surround the filter region **24** with a width d in the cavity layer **21**.

As FIG. **1** illustrates, the front face (end face on the light-transmitting substrate side) **25***a* of the surrounding region **25** has substantially the same height as with a part **24***h* located closest to the light-transmitting substrate **3** in the front face (first mirror layer forming surface) **24***a* of the filter region **24** or is positioned nearer to the light-transmitting substrate **3** than is this part **24***h*. The front face (end face on the light-transmitting substrate side) **26***a* of the connecting region **26** has substantially the same height as with a part **24***l* located closest to the light-detecting substrate **4** in the front face **24***a* of the filter region **24** or is positioned nearer to the light-detecting substrate **4** than is this part **24***l*. On the other hand, the rear face **24***b* of the filter region **24**, the rear face **25***b* of the surrounding region **25**, and the rear face **26***b* of the connecting region **26** are substantially flush with each other. Here, a side face **25***c* of the surrounding region **25** is flush with a side face **3***c* of the light-transmitting substrate **3** and a side face **4***c* of the light-detecting substrate **4**. However, a gap on the order of 0 to 100 μm may occur between the side face **3***c* of the light-transmitting substrate **3** and the side face **4***c* of the light-detecting substrate **4**.

The light-transmitting substrate **3** is arranged on the DBR layer **22** side of the cavity layer **21** and joined to the cavity layer **21** and DBR layer **22** through a coupling layer (first coupling layer) **11**. The light-detecting substrate **4** is arranged on the DBR layer **23** side of the cavity layer **21** and joined to the cavity layer **21** and DBR layer **23** through a coupling layer (second coupling layer) **12**. Each of the coupling layers **11**, **12** arranged between the interference filter unit **20** and the light-transmitting substrate **3** and light-detecting substrate **4** is a silicon oxide film formed by a film forming process using TEOS (Tetraethyl Orthosilicate, Tetraethoxysilane) as a material gas and has a thickness on the order of several hundred nm to 10 μm.

In thus constructed spectroscopic sensor **1**, when light incident on the light-transmitting substrate **3** from the front face **3***a* thereof passes therethrough to reach the rear face **3***b* thereof, only light in a predetermined wavelength range to be incident on the interference filter unit **20** is transmitted through the optical filter layer **5**. Then, when the light transmitted through the optical filter layer **5** is incident on the interference filter unit **20**, light in a predetermined wavelength range is selectively transmitted therethrough according to its incident position. That is, a wavelength of light to enter each channel of the light-receiving unit **6** of the light-detecting substrate **4** is uniquely determined by the thicknesses and kinds of the DBR layers **22**, **23** and thickness of the cavity layer **21** at the incident position. As a consequence, light having a different wavelength is detected for each channel of the light-receiving unit **6** in the light-detecting substrate **4**.

In the spectroscopic sensor **1**, as explained in the foregoing, the cavity layer **21** is a silicon oxide film and thus can stabilize its form, light transmittance, refractive index, and the like more than when made of a resin material. The coupling layers **11**, **12** are silicon oxide films and thus can stabilize the transmission characteristic of the light advancing from the light-transmitting substrate **3** to the interference filter unit **20** and that of the light progressing from the interference filter unit **20** to the light-detecting substrate **4** more than when made of resin materials. The fact that the cavity layer **21** and coupling layers **11**, **12** are silicon oxide films can also prevent their quality from being degraded by changes in temperature, high humidity, and the like of the environment where they are in use. Specifically, the cavity layer **21** and coupling layers **11**, **12** can prevent moisture absorption which may occur if they are made of resin materials, while suppressing thermal expansion and contraction more, so as to become more thermally stable, than when made of resin materials. Therefore, the spectroscopic sensor **1** becomes extremely reliable.

The cavity layer **21** is a silicon oxide film formed by thermally oxidizing silicon. This stably yields the cavity layer **21** with high quality at low cost.

The coupling layers **11**, **12** are silicon oxide films formed by a film forming process using TEOS as a material gas. This can form the coupling layers **11**, **12** at low temperature and high speed with low stress, so as to prevent the cavity layer **21** and DBR layers **22**, **23** from being damaged, whereby the cavity layer **21** and DBR layers **22**, **23** are obtained with high quality.

The optical filter layer **5** is formed on the light-transmitting substrate **3** so as to oppose the DBR layer **22**. This allows light in a predetermined wavelength to become efficiently incident on the interference filter unit **20**.

Additionally, in the spectroscopic sensor **11**, the filter region **24** is surrounded by the surrounding region **25** with the predetermined distance d therebetween in the cavity layer **21**, while the end part **24***e* of the filter region **24** and the end part **25***e* of the surrounding region **25** are connected to each other by the connecting region **26**. As a consequence, any external force acting in a direction perpendicular to the direction in which the light-transmitting substrate **3** and light-detecting substrate **4** oppose each other is buffered by the surrounding region **25** and connecting region **26**, whereby the filter region **24** can be prevented from being damaged.

The front face **25***a* of the surrounding region **25** has substantially the same height as with the part **24***h* located closest to the light-transmitting substrate **3** in the front face **24***a* of the filter region **24** or is positioned nearer to the light-transmitting substrate **3** than is this part **24***h*. As a consequence, any external force acting in a direction parallel to the direction in which the light-transmitting substrate **3** and light-detecting substrate **4** oppose each other (e,g., an external force applied upon direct bonding between coupling layers **11***a*, **11***b* or **12***a*, **12***b* which will be explained later) can be received by the surrounding region **25**, so as to be prevented from damaging the filter region **24**.

The front face **26***a* of the connecting region **26** has substantially the same height as with the part **24***l* located closest to the light-detecting substrate **4** in the front face **24***a* of the filter region **24** or positioned nearer to the light-detecting substrate **4** than is this part **24***l*. As a consequence, any external force acting in a direction perpendicular to the direction in which the light-transmitting substrate **3** and light-detecting substrate **4** oppose each other can be prevented from being directly exerted on the front face **24***a* of the filter region **24**, which is a surface for forming the DBR layer **22**.

A method for manufacturing the above-mentioned spectroscopic sensor **1** will now be explained. First, as FIG. **3** illustrates, one main face **50***a* of a silicon substrate **50** and the other main face **50***b* thereof are thermally oxidized, so as to form silicon oxide films **52** on one main face **51***a* of a handle substrate **51** made of silicon and the other main face **51***b* thereof, and the silicon oxide film **52** formed on the one main face **51***a* or other main face **51***b* of the handle substrate **51** is employed as a surface layer **53**. Here, the silicon oxide film **52** formed on the one main face **51***a* of the handle substrate **51** is employed as the surface layer **53**. The surface layer **53** has a thickness of about 1000 nm.

Subsequently, as FIGS. **4** and **5** illustrate, a resist layer **54** for etching to produce a plurality of cavity layers **21** arranged in a matrix is formed on the surface layer **53**. Then, using the resist layer **54** as a mask, the surface layer **53** provided on the handle substrate **51** is etched (etched back), so as to form a plurality of cavity layers **21** arranged in a matrix (first step).

Next, as FIG. **6** illustrates, the DBR layer **22** is formed on the cavity layer **21** for each part corresponding to one spectroscopic sensor **1** (second step). For forming the DBR layer **22**, film forming by ion plating, vapor deposition, sputtering, or the like and patterning by photoetching and liftoff or etching are performed. Since one spectroscopic sensor **1** is provided with one cavity layer **21** here, when forming the DBR layer **22**, the film forming may be performed on the whole surface so as to cover all the cavity layers **21** instead of patterning each part corresponding to one spectroscopic sensor **1**. Subsequently, as FIG. **7** illustrates, a silicon oxide film is formed on the cavity film **21** such as to cover the DBR layer **22** by a film forming process using TEOS as a material gas, and its surface is flattened by CMP (Chemical Mechanical Polishing), thus forming the coupling layer **11***a*.

The film forming process using TEOS as a material gas enables film forming at low temperature (e.g., at a film forming temperature of 200° C. or lower) and high speed with low stress by plasma CVD, LP-CVD, AP-CVD, or the like. In the plasma CVD, TEOS is supplied by bubbling with an He gas, heating with a heater, or the like and caused to generate a plasma-assisted decomposition reaction within a chamber, so as to react with an O_2 gas, thereby forming the silicon oxide film.

On the other hand, as FIG. **8** illustrates, a light-transmitting wafer **30** including a plurality of light-transmitting substrates **3** arranged in a matrix is prepared, and the optical filter layer **5** is formed for each part corresponding to the light-transmitting substrate **3** on the light-transmitting wafer **30** (i.e., on the light-transmitting substrate **3**). When forming the optical filter layer **5** from a dielectric multilayer film, film forming by ion plating, vapor deposition, sputtering, or the like and patterning by photoetching and liftoff or etching are performed. When forming from an organic color filter, the optical filter layer **5** is patterned by exposure and development or the like as with a photoresist. Since one spectroscopic sensor **1** is provided with one optical filter layer **5** here, when forming the optical filter layer **5**, the film forming may be performed on the whole surface so as to cover all the light-transmitting wafer **30** instead of patterning each part corresponding to one spectroscopic sensor **1**. Subsequently, as FIG. **9** illustrates, a silicon oxide film is formed on the light-transmitting wafer **30** such as to cover the optical filter layer **5** by a film forming process using TEOS as a material gas, and its surface is flattened by CMP, thus forming the coupling layer **11***b*.

Next, as FIGS. **10** and **11** illustrate, the DBR layer **22** and the optical filter layer **5** are caused to oppose each other for each part corresponding to one spectroscopic sensor **1**, and the respective surfaces of the coupling layers **11***a*, **11***b* are directly bonded (e.g., by surface-activated bonding) to each other, thus joining the handle substrate **51** and the light-transmitting wafer **30** to each other (third step). That is, the light-transmitting substrate **3** is joined onto the DBR layer **22** such that the DBR layer **22** and the optical filter layer **5** oppose each other through the coupling layer **11**. When the optical filter layer **5** is not formed on the light-transmitting wafer **30**, the coupling layer **11***b* as a flattening layer is unnecessary.

Subsequently, as FIG. **12** illustrates, the silicon oxide film **52** formed on the other main face **51***b* of the handle substrate **51** and a part of the handle substrate **51** on the other main face **51***b* side are ground, so that the handle substrate **51** becomes thinner. Then, as FIG. **13** illustrates, the handle substrate **51** is wet- or dry-etched, so as to remove the handle substrate **51** from the cavity layer **21** (fourth step). Here, the silicon oxide film **52** formed on the other main face **51***b* of the handle substrate **51** and the handle substrate **51** may be removed by wet or dry etching without grinding.

Next, as FIG. **14** illustrates, the DBR layer **23** is formed in the same manner as with the DBR layer **22** on the cavity layer **21** exposed by removing the handle substrate **51** (fifth step). As a consequence, for each part corresponding to one spectroscopic sensor **1**, the DBR layers **22**, **23** oppose each other through the cavity layer **21**, thereby forming the interference filter unit **20**. Then, a part corresponding to one spectroscopic sensor **1** becomes a spectroscopic filter substrate **9**, whereby a spectroscopic filter wafer **90** including a plurality of spectroscopic filter substrates **9** arranged in a matrix is produced. Since one spectroscopic sensor **1** is provided with one cavity layer **21** here, when forming the DBR layer **23**, the film forming may be performed on the whole surface so as to cover all the cavity layers **21** instead of patterning each part corresponding to one spectroscopic sensor **1**.

Thereafter, as FIG. **15** illustrates, a silicon oxide film is formed on the cavity layer **21** such as to cover the DBR **23** by a film forming process using TEOS as a material gas, and its surface is flattened by CMP, thus forming the coupling layer **12***a*. On the other hand, as FIG. **16** illustrates, a light-detecting wafer **40** including a plurality of light-detecting substrates **4** is prepared. Then, a silicon oxide film is formed on the light-detecting wafer **40** such as to cover the light-receiving units **6** by a film forming process using TEOS as a material gas, and its surface is flattened by CMP, thus forming the coupling layer **12***b*.

Next, as FIGS. **16** and **17** illustrate, the DBR layer **23** and the light-receiving unit **6** are caused to oppose each other for each part corresponding to one spectroscopic sensor **1**, and the respective surfaces of the coupling layers **12***a*, **12***b* are directly bonded to each other, thus joining the spectroscopic filter wafer **90** and the light-detecting wafer **40** to each other (sixth step). That is, the light-detecting substrate **4** is joined onto the DBR layer **23** such that the DBR layer **23** and the light-receiving unit **6** oppose each other through the coupling layer **12**.

Subsequently, as FIG. **18** illustrates, the rear face of the light-detecting wafer **40** is ground, polished, etched, and so forth, such that the light-detecting wafer **40** is thinned to a thickness on the order of 10 to 150 μm. Then, a through-hole is formed by etching in a part corresponding to front wiring, and through wiring, back wiring, and the like are formed, so as to produce the lead **7** for each part corresponding to one spectroscopic sensor **1**. Further, the bump **8** is formed on the rear face of the light-detecting wafer **40** for each part corresponding to one spectroscopic sensor **1**. Finally, the spectroscopic filter wafer **90** and light-detecting wafer **40** joined to each other are diced into each part corresponding to one spectroscopic sensor **1**, so as to yield a plurality of spectroscopic sensors **1**. Pad parts such as the front wiring and back wiring constituting the leads **7** may be not only embedded in the front and rear faces of the light-detecting wafer **40** (i.e., light-detecting substrate **4**), but also disposed thereon so as to project therefrom by their thickness, for example.

As explained in the foregoing, the method for manufacturing the spectroscopic sensor **1** forms the cavity layer **21** by etching the surface layer **53** disposed on the handle substrate **51**. Thus forming the cavity layer **21** by etching with the handle substrate **51** can stably yield the cavity layer **21** with a high precision. Further, after forming the cavity layer **21** and DBR layers **22**, **23** on the light-transmitting substrate **3** side, the light-detecting substrate **4** is joined thereto. This can prevent the light-detecting substrate **4** from being damaged in the processes for forming the cavity layer **21** and DBR layers **22**, **23**. Hence, this method for manufacturing the spectroscopic sensor **1** can yield the highly reliable spectroscopic sensor **1**.

Since the spectroscopic filter wafer **90** and the light-detecting wafer **40** are joined to each other after inspecting performances of each spectroscopic filter substrate **9** in the spectroscopic filter wafer **90**, the light-detecting wafer **40** can be prevented from being wasted because of failures on the spectroscopic filter wafer **90** side.

Since the silicon oxide film **52** formed on one main face **51***a* of the handle substrate **51** made of silicon is employed as the surface layer **53**, the cavity layer **21** can stably be obtained at low cost with high quality. Also, since both main faces **50***a*, **50***b* of the silicon substrate **50** are thermally oxidized so as to form the silicon oxide films **52** on both main faces of the handle substrate **51** made of silicon, the handle substrate **51** is restrained from waiving. Hence, the cavity layer **21** can stably be obtained with a high precision.

The optical filter layer **5** is formed on the light-transmitting substrate **3**, and then the light-transmitting substrate **3** is joined onto the DBR layer **22** such that the DBR layer **22** and the optical filter layer **5** oppose each other. This can make light in a predetermined wavelength range efficiently incident on the interference filter unit **20**.

When etching the surface layer **53** disposed on the handle substrate **51** while using the resist layer **54** as a mask, a part corresponding to the groove G in the resist layer **54** is removed in advance, so that a part corresponding to the groove G in the surface layer **53** is exposed at first. When the part corresponding to the groove G in the surface layer **53** is exposed, oxygen breaks away from the surface layer **53** made of SiO_2, so as to work as an etchant for the resist layer **54**. Here, the part corresponding to the groove G in the surface layer **53** surrounds the part corresponding to the filter region **24** in the surface layer **53**. Therefore, the whole part corresponding to the filter region **24** in the surface layer **53** is stably fed with oxygen and, as a result, reliably etched.

Without such oxygen supply, the etchant density distribution is likely to be biased by a loading effect and the like (e.g., the etchant is supplied more and less in the peripheral and center parts of the handle substrate **51**, respectively), so that the form of the filter region **24** produced by etching may vary depending on locations in the handle substrate **51**. In particular, when the resist layer **54** is made of an organic material, the etching rate varies greatly depending on the state of supplying oxygen as the etchant, whereby the above-mentioned supply of oxygen is very important.

When dicing the spectroscopic filter wafer **90** and light-detecting wafer **40** joined to each other into each part corresponding to one spectroscopic sensor **1**, chipping and the like can be prevented from occurring, since the spectroscopic filter wafer **90** and light-detecting wafer **40** are firmly integrated together as a whole by direct bonding between the coupling layers **11***a*, **11***b* and between the coupling layers **12***a*, **12***b*.

The relationship between the resist layer **54** and the cavity layer **21** will now be explained. As FIG. **19** illustrates, the resist layer **54** is formed on a flat surface (see a solid line in FIG. **19**) of the cavity layer **21** before etching (i.e., the surface layer **53**). The resist layer **54** has a three-dimensional form corresponding to the shape of the cavity layer **21** to be formed (i.e., the cavity layer **21** after etching). Such a resist layer **54** can be formed by utilizing a photomask whose transmittance is adjusted according to locations, photolithography or EB lithography whose amount of dose is adjusted according to locations, nanoimprinting, and the like.

When performing etch back (i.e., whole surface etching) based on the form of the resist layer **54**, the etching rate for the resist layer **54** and cavity layer **21** may be adjusted depending on etching conditions. This can produce various forms of cavity layers **21** from the resist layer **54** having one kind of form. In the case illustrated in FIG. **19**, the etching rate for the resist layer **54** is about twice as fast as that for the cavity layer **21**, so that the inclination of the surface of the cavity layer **21** after etching (see a dash-single-dot line in FIG. **19**) is milder than that of the surface of the resist layer **54** (see a broken line in FIG. **19**).

A monitor pattern disposed on the handle substrate **51** will now be explained. While the surface layer **53** is formed by a substantially constant thickness on the handle substrate **51** as FIG. **4** illustrates, not only the resist layer **54** for forming a plurality of cavity layers **21** by etching, but resist layers **55** as a monitor pattern are also formed on the surface layer **53** as FIG. **20** illustrates. The resist layers **54**, **55** are integrally formed by utilizing the photomask, photolithography or EB lithography, nanoimprinting, and the like as mentioned above.

The resist layers **55** as a monitor pattern are grouped by a plural number (9 here), and the resulting groups are arranged at a plurality of locations (4 peripheral locations and 1 center location here) on the handle substrate **51**. Each of the grouped resist layers **55** is formed by a substantially constant thickness corresponding to its corresponding one of a plurality of parts of one resist layer **54**. For example, the grouped resist layers **55** have the thickness of a predetermined part of the resist layer **54** corresponding to a predetermined part of the filter region **24**, the thickness of a predetermined part of the resist layer **54** corresponding to a predetermined part of the surrounding region **25**, and the thickness of a predetermined part of the resist layer **54** corresponding to a predetermined part of the connecting region **26** (i.e., the bottom face of the groove G).

As a consequence, measuring the thickness of the surface layer **53** in a part stripped of the resist layer **55** as a monitor pattern with an optical thickness meter at a predetermined timing such as that in the middle of etching the surface layer **53** or after the completion thereof can acquire the thickness of a predetermined part of the cavity layer **21** corresponding thereto. When the measurement timing is in the middle of etching the surface layer **53**, at which the resist layer **54** remains in a predetermined part of the cavity layer **21**, the thickness of the resist layer **54** remaining in this part can be acquired by the same method.

Thus utilizing the resist layer **55** as a monitor pattern is very effective, since each cavity layer **21** is small, while the surface **24***a* of the filter region **24** is tilted, so that the thickness of the cavity layer **21** is hard to measure directly with an optical thickness meter. Further, since the resist layers **55** as a monitor pattern are arranged at a plurality of locations on the handle substrate **51**, how the etching progresses (progress distribution) in the whole surface layer **53** on the handle substrate **51** can be evaluated.

The thickness of the cavity layer **21** corresponding to a predetermined part of the filter region **24** can also be acquired in the following manner. That is, the difference in level between the surface of the cavity layer **21** corresponding to the predetermined part of the filter region **24** and the bottom face of the groove G is measured by an AFM (Atomic Force Microscope), a step gauge of a probe type, or the like at a predetermined timing such as that in the middle of etching the surface layer **53** or after the completion thereof. On the other hand, in a part stripped of the resist layer **55** as a monitor pattern corresponding to the bottom face of the groove G, the thickness of the surface layer **53** is measured by an optical thickness meter. Then, the difference in level between the surface of the cavity layer **21** and the bottom face of the groove G is added to the thickness of the surface layer **53** as measured, so as to compute the thickness of the cavity layer **21** corresponding to the predetermined part of the filter region **24**. When the measurement timing is in the middle of etching the surface layer **53**, at which the resist layer **54** remains in a part corresponding to the predetermined part of the cavity layer **21**, the thickness of the resist layer **54** remaining in this part can be acquired by the same method.

While an embodiment of the present invention is explained in the foregoing, the present invention is not limited thereto. For example, various materials and forms may be employed for constituent members of the spectroscopic sensor without being limited to those mentioned above.

The spectroscopic sensor may comprise a plurality of interference filter units for selectively transmitting therethrough light in a predetermined wavelength range according to an incident position thereof. A spectroscopic sensor comprising a plurality of interference filter units will now be explained. As FIG. **21** illustrates, this spectroscopic sensor **1** comprises a plurality of interference filter units **20**A, **20**B. The interference filter units **20**A, **20**B are arranged in a row longitudinally of the spectroscopic sensor **1** between the light-transmitting substrate **3** and the light-detecting substrate **4**.

In the cavity layer **21**, as FIGS. **21** and **22** illustrate, filter regions **24** formed for the interference filter units **20**A, **20**B, respectively, are juxtaposed to each other, while each filter region **24** is held between DBR layers **22**, **23**. A surrounding region **25** surrounds the juxtaposed filter regions **24**, **24** with a predetermined distance d therefrom when seen in the incident direction of light. A connecting region **26** connects an end part on the light-detecting substrate **4** side of the juxtaposed filter regions **24**, **24** and an end part on the light-detecting substrate **4** side of the surrounding region **25** to each other.

The respective DBR layers **22** for the interference filter units **20**A, **20**B differ from each other in their kinds, and their boundaries may overlap each other partly, be in contact with each other with no gap therebetween, or be separated from each other by a gap of about 5 μm, for example. The respective DBR layers **23** for the interference filter units **20**A, **20**B differ from each other in their kinds, and their boundaries may overlap each other partly, be in contact with each other with no gap therebetween, or be separated from each other by a gap of about 5 μm, for example. Examples of the two DBR layers different from each other in their kinds include films constituted by different materials and (single-layer or multilayer) films made of the same materials with different thicknesses. The respective optical filter layers **5** for the interference filter units **20**A, **20**B differ from each other in their kinds, and their boundaries may overlap each other partly, be in contact with each other with no gap therebetween, or be separated from each other by a gap of about 5 μm, for example.

In thus constructed spectroscopic sensor **1**, when light incident on the light-transmitting substrate **3** from the front face **3***a* thereof passes through the light-transmitting substrate **3** and reaches the rear face **3***b* thereof, only light in a predetermined wavelength range to be incident on the interference filter units **20**A, **20**B is transmitted through the optical filter layer **5**. When the light transmitted through the optical filter layer **5** is incident on any of the interference filter units **20**A, **20**B, light in a predetermined wavelength range selectively passes therethrough according to its incident position. That is, a wavelength of light to enter each channel of the light-receiving unit **6** of the light-detecting substrate **4** is uniquely determined by the thicknesses and kinds of the DBR layers **22**, **23** and thickness of the cavity layer **21** at the incident position. As a consequence, light having a different wavelength is detected for each channel of the light-receiving unit **6** in the light-detecting substrate **4**.

Colored glass or filter glass which transmits therethrough light in a predetermined wavelength range may also be used as a material for the light-transmitting substrate **3**. Another optical filter layer may be formed on the front face **3***a* of the light-transmitting substrate **3** in addition to or in place of the optical filter layer **5**. The light-detecting substrate **4** is not limited to the one-dimensional sensor, but may be a two-dimensional sensor. The thickness of the cavity layer **21** may vary two-dimensionally or stepwise. A single-layer reflective metal film of AL, Au, Ag, or the like may be used as a mirror layer in place of the DBR layers **22**, **23**. The spectroscopic sensor may also be constructed as an SMD (Surface Mount Device) instead of a CSP.

The coupling layers **11**, **12** may also be silicon oxide films formed by plasma CVD using a silane gas, coating type SOG (Spin On Glass), vapor deposition, sputtering, or the like. Joining through an optical resin layer or at an outer edge part of the spectroscopic sensor **1** may be employed in place of the joining through the coupling layers **11**, **12** (i.e., direct bonding). The joining through the optical resin layer may use any of optical resins such as organic materials based on epoxy, acrylic, and silicone and hybrid materials made of organic and inorganic substances as a material for the optical resin layer. The joining at the outer edge part of the spectroscopic sensor **1** can be achieved by low-melting glass, solder, or the like while keeping a gap with a spacer. In this case, the region surrounded by the joint may be left as an air gap or filled with an optical resin.

A silicon oxide film may be formed on one main face of the handle substrate made of silicon by a film forming process using TEOS as a material gas, plasma CVD using a silane gas, coating type SOG, vapor deposition, sputtering, LP-CVD, or the like and employed as a surface layer. Silicon oxide films may be formed on both main faces of the handle substrate made of silicon by LP-CVD instead of thermal oxidization, and the silicon oxide film formed on one of the main faces of the handle substrate may be used as a surface layer. That is, the cavity layer that is a silicon oxide film is not limited to the one formed by thermally oxidizing silicon. However, forming the silicon oxide film by thermal oxidization has merits in that the cavity layer becomes a denser film, has better uniformity in thickness, incurs smaller amounts of impurities, and exhibits more stable optical characteristics such as transmittance and refractive index than when made by the other methods mentioned above.

INDUSTRIAL APPLICABILITY

The present invention can provide a highly reliable spectroscopic sensor.

REFERENCE SIGNS LIST

1 . . . spectroscopic sensor; **3** . . . light-transmitting substrate; **4** . . . light-detecting substrate; **5** . . . optical filter layer; **11** . . . coupling layer (first coupling layer); **12** . . . coupling layer (second coupling layer); **20**, **20**A, **20**B . . . interference filter unit; **21** . . . cavity layer; **22** . . . DBR layer (first mirror layer); **23** . . . DBR layer (second mirror layer)

The invention claimed is:

1. A spectroscopic sensor comprising:

an interference filter unit, having a cavity layer and first and second mirror layers opposing each other through the cavity layer, for selectively transmitting therethrough light in a predetermined wavelength range according to an incident position thereof;

a light-transmitting substrate, arranged on the first mirror layer side, for transmitting therethrough light incident on the interference filter unit;

a light-detecting substrate, arranged on the second mirror layer side, for detecting the light transmitted through the interference filter unit; and

a first coupling layer arranged between the interference filter unit and the light-transmitting substrate;

wherein the cavity layer and the first coupling layer are silicon oxide films,

the thickness of the cavity layer varies between the first and second mirror layers,

the thickness of the first coupling layer varies such that the light-transmitting substrate and the light-detecting substrate are arranged parallel to each other,

the cavity layer has a filter region held between the first and second mirror layers, and a surrounding region continuously surrounding the whole perimeter of the filter region as seen in a direction in which the light-transmitting substrate and the light-detecting substrate oppose each other,

the cavity layer is formed continuously over the filter region and the surrounding region,

an entire face on the light-transmitting substrate side of the surrounding region has substantially the same height as a part of a face of the filter region on which the first mirror layer is formed located closest to the light-transmitting substrate or the entire face on the light-transmitting substrate side of the surrounding region is positioned nearer to the light-transmitting substrate than the part,

the filter region overlaps with a light-receiving unit of the light-detecting substrate and the surrounding region does not overlap with the light-receiving unit as seen in the direction in which the light-transmitting substrate and the light-detecting substrate oppose each other, and

the thickness of the filter region varies between the first and second mirror layers.

2. A spectroscopic sensor according to claim **1**, further comprising a second coupling layer arranged between the interference filter unit and the light-detecting substrate;

wherein the second coupling layer is a silicon oxide film.

3. A spectroscopic sensor according to claim **1**, further comprising an optical filter layer, formed on the light-transmitting substrate so as to oppose the first mirror layer, for transmitting therethrough light in the predetermined wavelength range.

4. A method for manufacturing a spectroscopic sensor according to claim **1**, the method comprising:

a step of forming the cavity layer made of a silicon oxide film;

a step of forming the first mirror layer on the cavity layer;

a step of joining the light-transmitting substrate on the first mirror layer via the first coupling layer made of a silicon oxide film

a step of forming the second mirror layer on the cavity layer; and

a step of joining the light-detecting substrate on the second mirror layer via a second coupling layer made of a silicon oxide film.

5. A method for manufacturing a spectroscopic sensor according to claim **4**, wherein, the step of forming the cavity layer forms the cavity layer made of the silicon oxide film by thermally oxidizing silicon.

6. A method for manufacturing a spectroscopic sensor according to claim **4**, wherein, the step of joining the light-transmitting substrate forms the first coupling layer made of the silicon oxide film by a film forming process using TEOS as a material gas.

7. A method for manufacturing a spectroscopic sensor according to claim **4**, wherein, the step of joining the light-detecting substrate forms the second coupling layer made of the silicon oxide film by a film forming process using TEOS as a material gas.

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